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THE UNIVERSITY OF ALBERTA

Uses of Computers in Science Teaching: What a Teacher of Science Should Know

BY

A. Allan PEET

A THESIS
SUBMITTED TO THE FACULTY OF GRADUATE STUDIES AND RESEARCH
IN PARTIAL FULFILMENT OF THE REQUIREMENTS FOR THE DEGREE
OF Master of Education.

Department of Secondary Education

EDMONTON, ALBERTA
Fall 1987

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THE UNIVERSITY OF ALBERTA

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The undersigned certify that they have read, and recommend to the Faculty of Graduate Studies and Research for acceptance, a thesis entitled Uses of Computers in Science Teaching: What a Teacher of Science Should Know submitted by A. Allan Peet in partial fulfilment of the requirements for the degree of Master of Education.

M. A. Nay

Supervisor

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Date: September 25 1987

ABSTRACT

This study sought to identify the specific background knowledge, skills, and resources that are needed by a teacher for effective use of a computer in teaching science. Eighteen uses of computers for science instruction were identified in the literature and classified according to the preparation, teaching/learning, or testing/evaluation phase of teacher activity. A questionnaire probing the level and nature of the teacher's experience with, and feasibility of, these uses was devised and, after pilotting, administered to seventy-five science teachers. Analysis of the responses to the questionnaire from the fifty respondents indicated five categories of general knowledge required by a teacher for effective use of computers in a science classroom: operating and programming, hardware and peripherals, software and courseware, implementation of the application, and impact on the teacher. Subsequent interviews with thirty-one of the teachers revealed specific details which, supplemented by a review of the literature and the researcher's professional experience, helped to expand the scope of knowledge needed by a science teacher to use computers effectively. Each use was elaborated under the following sub-headings: definition, rationale for the use, considerations relevant to implementation, and illustrations of the use.

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CHAPTER I

Introduction to the Study

This chapter is an introduction to, and a description of, the nature of the study. Chapter II consists of a review of the literature contributing to the theoretical framework for the study as well as information on what a teacher should know to use computers effectively in science teaching. Chapter III mainly presents the design of the method of collecting data from science teachers on their uses of computers. Chapter IV gives a summary of the data on computer use collected from the teachers. Chapter V profiles the knowledge which a science teacher should have on computer uses. Chapter VI summarizes the findings of the study and presents some suggestions for research and development.

Background of the Study

The commencement of 'Automatic Teaching', signalled by that IBM digital computer in 1959 (Rath, Anderson, and Brainerd), though significant as an initiator, caused little effect on most teachers. The dimensions, both physical and economic, assured insulation of the teachers from those gargantuan monsters of the 60s and early 70s. With the successive entry of transistorized and large scale integrated circuits (chips), however, the size and cost decreased substantially. By comparison, in 1980, the increase in cost-efficiency of the computer during the previous ten years was equivalent to the marking down of a Rolls Royce car to a sticker price of $3 during the same period (Evans, 1979).

The multiple capabilities of the computer were now within the grasp of many potential users including the classroom teacher. This device was not unlike other instructional aids as it met with reactions ranging from rejection to studious indifference to fanaticism. The microcomputer, however, has unique operational characteristics:

- The programs require more care in their preparation than transparencies for overhead projectors.
- The programs are generally not transportable between different machines, in contrast to the standardization currently present with most other media.
- The keyboard with its function keys has a higher 'gadget-level' than any videotape recorder or television.
- Nothing apparently 'moves' when it worked; only electrons engaged in 'clandestine' operations.
- Portions of programs, as scarce as they are, can be less easily passed over by teachers during the teaching or learning activity than in transparencies, films, television programs.
- The programs have a capacity for interactive and varying performance unknown to other media.

- The computer can show aspects of science phenomena, such as simulations and graphics, that are beyond the capabilities of other media in the school environment.

Clearly, these foretold new requirements of a teacher who intended to use the computer for instruction.

Statement of the Problem

Teachers are supported in their professional activities, and the students aided in their learning, by many resources including print materials (e.g., texts), non-print materials (e.g., audiovisual aids), community sites, consultants, laboratory facilities and materials, etc. In the employment of these resources, the practicing teacher acquires knowledge and skills that are general and/or specific to each of these types of resources or methodologies. The microcomputer has brought with it new requirements for knowledge and skills in its use. The problem for this study then is to determine what constitutes the knowledge and skill needed for effective use of the computer in teaching science.

The primary purpose of this study was to identify the learning requirements of science teachers for using the computer in science teaching and the conditions that would facilitate this learning.

To achieve this, a second purpose emerged, namely, to determine the current uses, and those uses considered feasible, for computers in the teaching of secondary science.

Specifically, the directing questions that will be addressed in this study are:

"What are the uses to which the computer is being put or can be put by science teachers?" and

"What perceived specific background skills and resources does a teacher of science need in order to effectively use a computer in his/her professional work?"

Significance of the Study

The availability of computers and adequate software (courseware) for the various possible uses in the classroom, although necessary, are not sufficient requirements for the successful implementation of the computer in science education. The support needed, in the implementation process, by motivated and knowledgeable teachers has been described (Milner, 1980; Moursund, 1979). Yet, for all the urgent requirements for teachers who have a working knowledge of computers and their different applications in education, the present population of 'computer literate' teachers in Alberta is dwarfed by the microcomputers that are available in Alberta's schools. Surveys of schools continue to identify the predominant training requirement of most teachers as needing to know how to integrate computers with instruction (Petruk, 1986).

Further, the science teacher who is not aware of or who does not make use of the services available in a school, including those offered by a computer, causes the teacher and the teacher's students to miss the unknown benefits that may result. It is essential, therefore, for a balance of hardware and human resources and optimum utilization of all resources, that the requirements of 'computer literate' science teachers be identified to determine the range of skills and knowledge needed for the present and probable future uses of computer by teachers in science education.

This study attempts to provide a compendium of the needs of a computer literate science teacher. The information from the study may assist in defining the content of inservice courses or preservice workshops intended to support teachers who wish to use this aid.

A community of corporations, colleges, universities, employers, and professional associations currently offer, or are contemplating offering, courses for teachers who are considering the use of computers in their teaching activities. Each of these facilities provides a unique service to the teacher seeking entry to this activity.

Most teachers, however, have no basis on which to judge the merits of the contents of the available courses. The results of the study should form a basis for judging the worth of a course for supporting the uses of the computer that are being contemplated by the science teacher. Consequently, the study's greatest significance should be to guide the teacher in this endeavor. For instance, it may assist the pre-service or in-service teacher to select a course of study or it may assist personnel who are designing courses for science teachers.

Design of the Study

The knowledge or skill that is possessed by a teacher who is experienced in the uses of computers will be presumed to include that which is necessary for the teacher to effectively use a computer in the classroom. The design of this study, therefore, is directed towards the gathering of all possible information on effective computer use in science instruction. Three major sources of information have been identified and made use of in this study: the appropriate research literature on computer use, the experiences with computers of a selected sample of science teachers, and the researcher's own thoughts on this problem. The information on computer use that was collected is presented in a fashion deemed to be most useful to the teacher: information for the preparation for teaching, information for the teaching/learning activities, information for testing and evaluation. This study, therefore, employed a questionnaire and interviews, conducted in both the pilot and main stages, to determine, from practicing classroom science teachers, the learning needs of computer-using science teachers.

The main stage questionnaire (Appendix A), in which eighteen uses are described in detail and are classified according to the three phases of teaching, incorporates the framework for subsequent discussion about what a teacher should know about uses of computers in science teaching. It was used to

- provide a mechanism for identifying science teachers for inclusion in later interviews,
- present a profile of uses for consideration by the teacher respondents and interviewees, and
- gather initial information (Appendices B and C) about the specific activities and programs of each potential interviewee.

The interviews were to provide in-depth information about

- the nature of uses made by the the science teachers and
- the science teachers' perception of what knowledge was needed to enable the implementation of computers in science teaching.

Definition of Terms

BASIC:

An interpretive programming language, Beginners' All-purpose Symbolic Instructional Code, universally offered in the permanent operating memory of microcomputers.

Computer Literacy for Science Teachers:

The ability to select and effectively employ appropriate computer devices and programs in relevant educational situations.

Data Base:

The fields of information stored in a file of records and maintained by an operator using a host management program for entering, editing, and retrieving the data as available and as required.

Drill and Practice:

A procedure and program which provides a reinforcement, at a low cognitive level, of previously presented subject matter content by sequential display of stimuli to which the student responds. Feedback to the student is usually offered but inclusion of performance results in student records is optional.

Gaming:

The use of a programmed situation in which a recreational or 'play' component offers competition as motivation to bring the situation to the determination of a winner.

Computer Managed Instruction (CMI):

The educational practice of prescribing learning activities for students, and recording the results thereof, based on results of previous activities of that student that are maintained in the student's record.

Laboratory Instrumentation:

The use of computer technology to record data from laboratory instruments and/or sensors or to alter the process or parameters of an experimental operation by actuating controlling devices.

LOGO:

An interpretive, procedure-oriented, recursive programming language offering 'Turtle' graphics and devised for use by children.

Problem Solving:

The creation and subsequent testing by a student of a model of a system within a host program or through the use of high-level programming skills possessed by the student.

Simulation:

A representation of the behaviour of a phenomenon designed to substitute for the phenomenon.

Tutorial:

The presentation of subject matter by an interactive program which responds to the student portion of the instructional dialog by selecting appropriate branching routines .

Delimitations of the Study

1. The field examined in this study is that of science education and, hence, teaching science using computers (rather than teaching computing science, the domain wherein the activity is teaching about computers and the mechanics of using them).

2. The research literature on the effectiveness of using a computer in science teaching was not systematically

summarized because it was judged not to be an important source of information for the study owing to the limited amount of reported research that was of practical significance to a classroom teacher.

3. By design, the description of the learning requirements of a teacher of science in each use of computers is as comprehensive as possible and no relative importance is implied by the amount of description of any use or phase of activity.

4. In stating what a science teacher should know, no value judgement was placed on the importance of each use of computers, except implicitly in terms of the rationale given for each use.

5. The main focus is on what a science teacher should know to use computers effectively in a classroom, with only minor attention being given to how the teacher may become proficient in the use.

6. Some attention was given to the determinants underlying the implementation of computer use in science instruction but no exhaustive treatment of the implementation dimension is given.

Limitations of the Study

1. The results of this study describe the learning requirements of science teachers; therefore, some of these findings will not be applicable to teachers of other subjects within the school.

2. The reported level and frequency of use of computers by the teachers was not systematically verified. The teachers are assumed to have made equivalent assessments of their own levels of experience and feasibility of using the computer for science teaching and, as a result, selection of teachers for later interview, on the basis of these questionnaire responses, was deemed equitable.

3. The results were based on three sources of information, namely, the relevant literature, the science teachers who were using computers, and the professional knowledge and experience of the researcher. There was a limit to the amount of useful information that could be obtained for the study from each source. In addition, there may be other sources of useful information on computer use in science teaching of which the researcher was not aware.

4. The information on which this study is based were the experiences of science teachers on the "leading edge" of computer implementation in the public schools and may not represent the knowledge requirements of other teachers who do not perceive the use of computers the same way or follow a less rigorous path to implementation of computers into their classes.

CHAPTER II

REVIEW OF RELATED LITERATURE

The flood of material written about computers and science teaching/learning covers many aspects. A division of the topics yields two broad areas:

a) The utility of the computer, i.e., "What the machine can do." and

b) The impact on the teacher, i.e., "What the teacher will do."

The teacher who stands at the threshold of using this aid has a wealth of information to gain in the first area; the assistance available to the teacher in the second area is sparse.

The first part of this chapter will examine the literature on the uses to which a computer can be put in the professional activities of a teacher and the learning activities of a student. Following this inventory of uses, the learning requirements of teachers will be examined, as they relate to these proposed uses of computers.

The Uses of Computers in Science Education

Gaede and Singletary (1979) identify seven stages in the teaching process, viz, goal identification, objective development, lesson design, lesson implementation, lesson evaluation, and lesson modification. At the risk of dressing a new model in old clothes or, perhaps, describing an 'automobile' as a 'horseless carriage' (Papert, 1980), the applications or uses of a computer in these stages of science teaching will be reduced to the perspective of a practicing teacher who is in one of three phases for each class taught: the teacher is getting ready to teach, or is teaching, or is 'cleaning up' after each group of students for which responsibility is held. This construct of the uses of the computer for teaching/learning is adopted to aid in presenting the uses to the participating teachers who are the respondents in this study. In this way, the general 'computers in science' topic is to be built on a framework familiar to all practicing science teachers.

Phase I: The Preparation Phase and Computer Use

The activity of a teacher prior to meeting with the students in the class involves making decisions relating to the selection of course content and sequence, choosing appropriate teaching methodology, preparation or selection of suitable materials, and personal preparation for effective contribution. Here, the computer can be an aid by getting information from a local or district memory and, if programmed accordingly, can make recommendations on the choices offered. Watts (1981) recognizes four uses of computers that belong to this pre-teaching activity: these are Curriculum Planning Applications, Professional Development Applications, Library Applications, and

Instructional Management Applications, to which list Roecks (1981) adds Institutional Coordination.

Curriculum Planning and Materials Preparation The proposed computerization (Merrills, 1982) of the Curriculum Resources Information Bank (C.R.I.B.) utilizes the large memory of a centrally-located 'maxi'computer which, on command, transmits, through the telephone lines, the instructional materials that the teacher requests. This previously-prepared curriculum information is then displayed for preview by the teacher and, if suitable, is printed for student use. The resource file that is 'down-loaded' may also contain suggestions for the teacher regarding relevant media, references, or activities. Soltzberg (1979) also considers here the local preparation of custom-tailored diagrams and illustrations using commercial programs.

Professional Development The teacher also is a potential beneficiary of this collection of material in a central data bank. The collective contributions of various colleagues and professional leaders become available for perusal and engagement in an in-service program supplemented with seminars (or 'round-table' multi-party conferences using the telephone connections).

Institutional Coordination Closely related to the above professional development of teachers is Roecks' (1981) recognition of the computer's capacity to aid in inter-institutional communication using the 'electronic mail-boxes' of a message facility into which specific- or group-addressed information is inserted for retrieval by the addressee(s) with their power for discretionary hard-copying. Included in this broad area of institutional coordination are maintenance of student records in school-district or -divisional computers.

Library Applications In addition to resource management usage by library staff, a science teacher (or student) may access a data bank, similar to Educational Resources Information Clearinghouse (E.R.I.C.), searching for titles not included in the large curriculum resources records described above.

Instructional Management Applications Notwithstanding its fifth listing here, the contributions by a Computer-Based Instructional Management System (Baker, 1971) are those necessary in proportion to the extent that personalized instructional strategies are implemented in a school. Using a cycle of criterion-based test scoring, diagnosis, prescription, and reporting, this application (in which educational objectives-dependent procedures, materials, and measuring instruments are integral) seeks to provide the means by which the teacher manages the educational enterprise so as to offer each learner an optimum set of educational experiences.

Phase II: The Teaching/Learning Act and Computers

Some attention has been focussed on the forms of the application of computers to the process of teaching and learning beyond that of an electronic after-image of the programmed instruction 'Teaching Machines' of the 1960s. Three of Sparkes' (1982) descriptions fall into this 'immediate' mode of use of the computer in the classroom: The Electronic {Chalk}board, The Universal Laboratory Instrument, and Computer-Assisted-Learning. Rushby (1979) expands computer assisted learning to include the Instructional Paradigm, Revelatory Paradigm, Conjectural Paradigm, and Emancipatory Paradigm. Lower, Gerhold, Smith, Johnson, and Moore (1979) view computer assisted instruction as having seven possible manners of employment: these are Problem-Tutorial, Objective-directed Tutorial and Drill, Quiz- or Test-mode, Pre-laboratory, Post-laboratory, Laboratory-extension, or Laboratory-substitution, each of which may employ a variety of strategies, viz., Drill-and-Practice, Tutorial, Simulation, or Gaming. Watts (1981) subsumes all of these under two classes; Instructional Aid Applications and Computer-Assisted-Learning Application, the distinction between these being the centrality, in the latter, of the computer to the direct instruction of the student.

Some of these specific uses of computers will now be discussed in detail.

Simulations When presented with a computer simulation, i.e., "a system designed to reproduce essential aspects of reality for the purpose of finding ways to manage, control, solve, and/or ultimately agree upon the best solution for a problem (Noonan, 1981)", a student is an explorer searching for the rules underlying the system by noting the effect on the system caused by adjusting the programmed parameters available. A science teacher would offer the student a simulation as a 'pseudo-experiment' when a demonstration or experiment

1. took too long (e.g., genetics experiments),
2. happened too quickly (e.g., capacitor discharge),
3. was too dangerous (e.g., radioactive decay),
4. required a complicated set-up (e.g., Millikan's oil-drop determination of charge/mass of an electron),
5. required expensive or difficult-to-obtain materials or apparatus (e.g., Maxwell-Boltzman distribution of velocities in a gas),
6. occurred in a hostile environment (e.g., satellite orbits),
7. caused undue stress to the environment (e.g., stream pollution) (Wright, 1981), or
8. involved several factors requiring complex mathematical analysis to identify the predominant variable(s) which could be more simply portrayed in an educational

simulation.

The usual purpose, then, is to supplement 'normal' laboratory activities. There are, however, auxiliary uses of laboratory-simulations that include the possibility of a) pre-laboratory orientation to equipment, procedures, and typical results, b) laboratory-extension to expand the range of conditions beyond those experienced by the students when the experiment was performed, and c) post-laboratory replication of procedures and 'number-crunching' to verify experimental results (Lower, et al, 1979; Mandell, 1982). Especially desirable for this application is the ability of the screen to exhibit, in addition to static alphanumeric characters, sketched figures which may depict animation.

Laboratory Instrumentation With the addition of appropriate matching electronic circuity (interfaces) to which may be attached sensors (transponders) or switches, the computer may record data from a multiplicity of experiments, e.g., the acceleration of a moving object, the dissolved oxygen of a solution, the voltage and temperature of an electrochemical cell, etc. The computer may only act as a fast recorder of these data or may also be programmed to analyze and display the data in a tabular or graphic form. The computer, again through interfaces at the output ports, may also control devices in an experiment, e.g., the release valve on a buret, an electromagnetic gate on a kinematics apparatus, a heater in a solution, etc.

Tutorial The instructional dialogue between the student and the computer has been viewed as the electronic analog of programmed instruction supplemented by the computer's enhanced ability for string checking of the student's responses and extensive branching to appropriate remedial discourse (Rushby, 1979). In this type of use, the student is an active participant (or respondent) to questions posed by the program; this same program has the capacity to evaluate the student's progress and to select the pace and extent to which the new material will be developed.

Drill-and-Practice A major purpose of drill-and-practice programs is the review and reinforcement of basic skills and concepts; matching of responses is required here as well as in the tutorial program. The branching for remediation and difficulty level is optional, as are diagnostic subroutines.

Gaming The element of competition, either with the computer or with other students, presents an element of motivation to a program. The determination of a 'winner' is the goal set by the program (Dennis, Muiznieks, and Stewart, 1979).

Electronic Chalkboard/Calculator The presentation to a class of prepared notes and displays on a computer screen is an alternate to the film loop or overhead projector. The ability to custom-design and display an electronic circuit with locally chosen component values and to note the resultant operational characteristics is 'bread-boarding' in a new dimension (Lewis, 1981).

Problem-Solving Nay and Merrills' (1982) computer-based scientific problem solving and Rushby's (1979) Conjectural Paradigm propose an expansionist's perspective on the student's use of a computer in science education not limited by the pre-planned structure present in most other programs. Here, the student specifies portions of, or constructs a model of, a real-world system and then notes the degree of conformity to or discrepancy with the real situation. The construction of this environment requires programming skills by the student or a high-level language (note the use of LOGO for mathematics) emulating artificial intelligence by the computer.

Phase III: Post-Class Testing and Evaluation

The utility of the computer in the support of the teacher after the learning situation is listed in Watts' (1981) taxonomy of Applications which include Administration, Research, Guidance and Special Services, and Testing. Baker (1971) views the testing components as only a component of an overall Management System where included are Pretest, Diagnostic or Progress Test, and Posttest. Rushby (1979) also regards many of these after-learning-content uses of computers under the general umbrella of Computer Managed Learning.

Discussion here will relate to the computer's use in the assessment of the student and of the educational program and the guidance offered to the student making a decision in career counselling.

Test Management The computer brings to this activity of teaching the editing features of an interactive word processing program, a large permanent memory, the faithful reproducibility of contents, the objective scoring (optional) of the responses, and the recording of item and test results. The next three features indicated below may be included in this general category.

Test Production The options available are for the computer to retrieve test questions from the item bank that have been previously entered from various sources (Eisele, 1979) or for the computer to generate unique questions using question templates into which appropriate random values are inserted resulting in a number of parallel test items all of which follow general and expected formats. Options for the teachers using the testing program are that the items may be visually selected item-by-item by the teacher or that a stratified random selection may be made by the computer with specified criteria acting as restraints such as level of difficulty, weighting by subject matter objective, cognitive level required, or type of response required (Johnson, 1981). The potential for 'make-up' tests with comparable characteristics is evident.

Test Scoring If the responses to the test items are multiple choice or true/false or if the test is given on the computer (on-line) and matching routines are available for short answers, then the answers may be scanned for scoring of responses.

Test Records After scoring, the results may be written to internal records and/or returned to the test user; a computer managed system may also offer recommendations for units to be covered or reviewed based on item and test results. The computer records may also contain qualitative, anecdotal descriptions of student achievement.

Test Item Analysis The records of results in the tests may be subject to the analysis of students' performance by software statistical analysis packages to determine the level of difficulty, quality of discrimination, etc., enabling the revision or substantiation of the items in the test bank.

Evaluation of Students/Program Records of performance results for tests permit the longitudinal tracking of the student's achievements and the comparison between groups which forms a basis for instructional decisions (Watts, 1981).

Career Guidance Although career counselling of students does not normally fall within the domain of activities of teachers, the science objectives frequently include references to occupations and industries where a knowledge of science is a prerequisite. As part of the realization of the maximum potential of each student, the CHOICES program, offered in association with the Federal Ministry of Manpower and Immigration, provides a pre-employment and training service here, usually through the Student Counselling Office of schools offering this resource.

Summary

The applications described above illustrate some separate aspects of the multi-faceted capabilities of the computer. In any specific application, the combined contribution of several features is possible, for example, a simulation, with graphics, may appear as part of a tutorial with records of the student's responses retained in internal files or, perhaps, the use of a computer-controlled 'intelligent' videodisc showing slides or moving sequences as visual prompts for, or as responses to, a student's comments in a drill-and-practice sequence.

Computer Literacy for Teachers

Characteristics of a computer literate teacher have been variously described in the literature.

In 1978, Madelaine Baum employed the Policy Delphi technique to identify the training needs of computer-using teachers (Dennis, 1979). Table 1 lists the twenty-four skills or items of knowledge that were considered "somewhat" or "very" important to proficient instructional computing by a majority of the participants (Dennis, 1978).

Muir and Forman (1982) formed a composite of various definitions of computer literacy that included

a) knowledge of the history of computing,
b) understanding of how computers work and how they can be programmed,
c) awareness of the computer as an aid to learning,
d) awareness of how the computer can be used as a problem solving tool,
e) insight into business and industrial applications, and
f) awareness of the present and possible future effects of computer technology on society.

These same components have been accepted by the Alberta Education Minister's Task Force on Computers in Schools as defining a computer literate adult (Romaniuk, 1983). These facets of computer literacy are noted to be applicable to the general public, adult and pupil alike, and are not

Table 1

Important Knowledge or Skills for Instructional Computing (From J.R. Dennis, 1978)

1. Familiarity with computerized teaching materials (i.e., instructional programs) in a variety of fields.
2. Ability to integrate computerized teaching materials into a course.
3. General knowledge of the functioning of CMI (computer-managed-instruction) systems.
4. Understanding of effective design of drill and practice materials.
5. Ability to apply computerized drill and practice in a variety of teaching situations.
6. Familiarity with computer simulations and models.
7. Experience in preliminary design and construction of a simulation.
8. Knowledge of the uses of simulations as teaching tools.
9. Ability to evaluate the effectiveness of a course that uses computerized teaching materials.
10. Ability to determine the computer needs of a school.
11. Ability to draft specifications (request for proposals) which set down the needs and desires of the school and invite proposals/bids from potential suppliers.
12. Ability to be highly critical of suppliers' proposals and their machines.
13. Ability to assemble data about proposed equipment to facilitate decision-making (costs, performance data, hardware characteristics, software support, etc.)
14. Familiarity with instructional games.
15. Knowledge of how to use instructional games appropriately and effectively in teaching.
16. Physical familiarity with computer equipment, i.e., everyday operation and use of a range of different machines.
17. Knowledge of trouble-shooting procedures and means of access to professional help, i.e., knowing how to determine if a piece of equipment is ailing, and if it is, knowing whom to call to fix it.
18. Knowledge of sources for computer materials.
19. Knowledge of how to improve less-than-adequate instructional computer programs.
20. Ability to evaluate the effectiveness of instructional computer programs.
21. Ability to instruct others in the social role and impact of computers in society.
22. Knowledge of alternative uses of computers in schools, e.g., as class-record-keepers, term-paper-editors, etc.
23. Awareness of the value of involving students in the development of computerized instructional materials.
24. Knowledge of processes of involving students in instructional materials development.

descriptive of computer professionals such as programmers or analysts.

Szabo (1983) notes six levels of computer literacy;

0) unaware [of the computer],
1) aware of its existence,
2) aware of some needs that can be met with computers,
3) aware of some needs that cannot be met with computers,
4) aware of problems created when bringing in computers to solve the needs in (2) above,
5) aware of how to prevent/solve problems in (4) [writer's emphasis].

The examination of these descriptions of computer literacy invokes two questions: Is this an exhaustive listing of characteristics of computer literacy? Are the characteristics of a computer literate science teacher a sub-set of, or a differently described set of characteristics? The first of these questions will be addressed in the remainder of this chapter; the second question is, in part, the goal of this study.

A Matrix of Computer Literacy An examination of the literature searching for other possible, previously unidentified, characteristics revealed the following information.

a) Surprisingly, in view of the frequent presence in introductory courses, none of the eleven references suggested that 'a knowledge of the history of computing' should be included in a definition of computing literacy.

b1) The range of significance attributable to 'an understanding of how computers work' extended from a two hour lesson (Lopez, 1981) up to two of Milner's seven courses (1980). Bork (1982) does not emphasize this and two articles (Moursund, 1979; Dickerson, 1981) make no reference to this component of computer literacy.

b2) An activity usually associated with adult computer literacy courses, 'an understanding of how computers can be programmed,' i.e., programming, registered as the most contentious with statements in references regarding the inclusion of programming in a Program of Studies. Recommendations favouring inclusion were made by Dennis (1978), Ingoldsby (1978), Milner (1980), Larson (1981), Lopez (1981), Bork (1982). Porter (1982) excludes programming as a requirement for 'Implementors' and notes the inclusion of authoring languages for 'Innovative Leaders' at one college and, at another college, programming sufficient for an understanding of implications for instructional design. Diem (1981) completely removes from teachers 'the onus of having to learn complete computer programming techniques.'

c) Not surprisingly, no conflicting statements were present in the discussions found in these articles from Education Journals regarding an 'awareness of the computer as an aid to learning'; only three articles (Dickerson, 1981; Ingoldsby, 1978; Larson, 1981) omitted reference to this component of computer literacy.

d) Less expression was given to an interest in an 'awareness of how the computer can be used as a problem-solving tool' with only five mentions (Dennis, 1978; Moursund, 1979; Larson, 1981; Porter, 1982; Bork, 1982).

e) Larson makes a solitary, and slight, reference to the 'insight into business and industrial applications' with a comment on students' automation of simple experiments.

f) Only three of the articles (Dennis, 1978; Henderson, 1978; Milner, 1980) recommend the inclusion of an 'awareness of the present and possible future effects of computer technology on society' in a literacy program.

Other aspects of computer literacy raised by the authors include

i) a study of research findings related to learning, teaching, curriculum development, and evaluation (Dennis, 1978)

ii) design, development, implementation, and evaluation of computer-based learning materials (Henderson, 1978; Milner, 1980; Porter, 1982; Bork, 1982)

iii) a background in Learning Theory (Bork, 1982).

Summary

It would appear from the above analysis that substantial differences in opinion exist regarding the abilities to be included in the repertoire of a computer-literate adult and that no single reference proposed an exhaustive, universally acceptable set. Firstly, programming skills and hardware knowledge, the 'meat and potatoes' of some introductory courses, are not universally accepted as necessary for teachers who are considering using computers in their teaching. Secondly, there are no references to the special needs, if there are any, for implementation of computers by teachers of subject areas, apart from a tendency to associate types of programs with subject areas, eg., text processing with English, simulation modelling with the sciences, graphics with geography, tutorials with mathematics, etc., (Lopez, 1981; Porter, 1982). Lastly, there is often more concern that teachers be computer literate than how teachers are to become computer literate.

CHAPTER III

DESIGN OF THE STUDY

Sources and Treatment of Data

As was stated in Chapter I, the data for this study came from three sources: the relevant research literature on computer use and teaching, a sample of science teachers who were found to be the most active in using computers at the time that the data was being collected, and related professional experiences of the researcher.

Some of the information from the relevant research literature on computer use is presented in chapter II. This information was helpful in identifying specific uses of computers in science teaching and developing a framework for classifying them. This framework is discussed in detail under the section below entitled 'The Main Stage for Collecting Data from Teachers.' Some of the information from the research literature is not mentioned in chapter II but is incorporated into the profile of uses presented in chapter V. Appropriate citation is given whenever such literature information is used.

The personal contribution to the study from the researcher has the following basis:

- twenty-three years of teaching science, including nineteen years specializing in high school physical science,
- two years of formal study at the graduate level of

computer operation and application to science teaching,
- four years of practical experience in applying computers to the three phases of teaching science, and
- six years of consideration of the question of the study about what a teacher should know to use computers effectively in science teaching.

The most important source of information on computer use in science instruction was the sample of teachers who were deemed to be active users. The remainder of this chapter describes how this information was gathered.

In concluding this section, it should be noted that the researcher collated the relevant information from the three sources into a profile of each use. These profiles are given in chapter V.

The Pilot Stage for Collecting Data from Teachers

The Purpose of the Pilot Stage

The refinement of the research procedure for the main study, the construction of a questionnaire of current and feasible educational uses of the computer by science teachers, and the determination of the needs of teachers to achieve these uses were the goals set for this pilot stage of data collection.

The Pilot Design

Because of the exploratory nature of the pilot stage, information about the science teachers' use of computers was sought by a semi-structured interview with the eight respondents. The interviews occurred after school hours and were audiotape recorded. The duration of the interviews was one-and-a-third to two hours.

The Sample

Science teachers employed by the Edmonton Public School Board were considered and, from these, four Senior High and four Junior High School teachers were chosen who were known to have been involved in using computers in teaching science. The teachers selected were nominated by the interviewer, by a researcher who was completing an implementation study in this area, and by system personnel when approached to identify contacts. The interviewer had, previous to the interview, met all but one of the interviewees and had already established a professional relationship with four of these teachers.

The Pilot Interviews

No written instrument (e.g., questionnaire) was administered to the respondents during the initial contact. Instead, two lists were made for the guidance of the interviewer:

1) The potential uses of the computer in science teaching (Appendix D).
2) The schedule of questions to be raised during the

interview (Appendix E).

Following the interview, important ideas were extracted verbatim from the audiotapes and stored in a computer text file and a 'hard copy' was made for the interviewer's perusal and analysis. Analysis was aided by construction of a chart using rows for each actual or projected use and columns for each of the interviewees statements. In each of the cells thus formed, relevant comments from the interview were noted.

The Pilot Questionnaire

Because the pilot teachers had made statements that resulted in redefinition of the uses and the categories of knowledge to be probed in the interviews in the main stage of the study, the seven pilot science teachers were asked to preview the questionnaire that had been constructed for the main stage. Their comments were collected, resulting in

- reformatting of the questionnaire to place the description of each use and the reaction by the teacher on the same page (to reduce page-turning), and
- an approximation of the time probably required to complete the questionnaire (to assess the burden to be placed on the teachers in the main stage).

The Pilot Interview Procedure

The interview method was found to be fruitful for allowing maximum contribution by the respondents within the general limits set by the research questions. The comments yielded an abundance of information on the current uses of the computer by the teachers in the survey. The comments by the teachers on the possible uses tended to be dependent, in part, on the image of the proposed uses as projected by the interviewer. A tendency for bias and/or for misunderstanding of the nature and/or the extent of computer use was considered possible in the teachers' responses to the interviews comments. Leading statements to the interviewee were not detected until the audiotape of the interviews was reviewed by the researcher following the interviews. The discussion on the needs for knowledge and/or skills required by science teachers tended to clarify the route taken by that specific teacher and, where not specifically addressed by questioning or volunteered by the interviewee, led to inferring of requirements from statements made by the teachers.

Implications of the Pilot Results for the Main Study

The time required for transcription and analysis of the interviews was extensive, requiring ten to fifteen hours per hour of interview. Although this was a heavy commitment, the results were more easily and thoroughly analyzed in comparision with just the notation of the main points, an activity requiring about three to five hours per hour of interview. Therefore, the pilot study indicated a need to be selective of those teachers to be interviewed in the main stage.

The perception of bias presented to the interviewers when describing the possible uses of the computer or needs of teachers suggested the use of standardized statements in the main stage to which the participating teachers could respond.

Both the time and bias concerns above could be solved by surveying a larger population of teachers and then, from the returns from these teachers, selecting those teachers who were exemplars of specific functions in the utilization of computers. The teachers could be interviewed to seek clarification or elaboration on statements made in the screening questionaire (Appendix A). This would tend to reduce the duplication of interviews where the respondents to the questionaire were perceived to hold similar views or have adopted similar uses.

The questions that guided the interview needed to be reevaluated for their level of emphasis on

- the construction of the profile of uses made or considered feasible; much of this information needed to be available from the initial contact through the questionnaire with the science teachers in the main stage of the study.
- the stages of implementation traversed by the interviewee reaching the current state.

This study is not of computer implementation by that teacher but recommendations by the teacher, who may possibly reflect on either his/her earlier stages of implementation but who hopefully will consider the actual, current requirements for that identified use and which could guide school policy on increasing use of computers in science teaching.

The pilot stage indicated the need for a questionaire, based on responses by participants in the pilot stage, permitting ready and more comprehensive identification of a) practical concerns relevant to conducting the study, such as

- those teachers who were most advanced in use of computers, and who would be the people to interview, and
- directions for formulating questions for interviews, and

b) those substantive concerns related to the information that was sought by the study, such as

- current or perceived uses of computers in science education, and
- needs of teachers using computers in science, particularly the benefits and costs, skills and knowledge, and pedagogical practices.

The Main Stage for Collecting Data from Teachers

The Questionnaire

The Purpose The purposes of the questionnaire were to obtain information about the nature of the experiences of s[illegible] science teachers with the various described uses of the computer and their assessment of the feasibility of each use and, thus, to

- provide a grounding for the devising of questions for the interview,
- identify teachers who could be interviewed later in the main stage, and
- aid in forming a structure for the learning needs of science teachers who would use computers.

The Instrument The first draft of the questionnaire that was designed for the study contained two major sections:

a) a description of each of nineteen uses of the computer according to a review of the literature and comments made by teachers during the pilot stage and

b) a form in which options and space were provided wherein the teachers could indicate

   i) the nature of their past or current experiences using computers in science teaching,

   ii) the perceived feasibility of their becoming involved in each of these uses, and

   iii) other comments about each computer use. These indications of interest in each use would form a basis for determining the potential of each teacher to contribute, in an intervew, to the study.

Informal evaluations by associates led to the following revisions made to the first draft of the questionnaire:

- addition of definitions of each of the four types of participation,
- addition of a scale to permit the respondees to indicate their level of involvement in each of the uses described,
- expansion of the space available for free responses to programs used and other comments,
- change in the physical dimensions of the printed material,
- rewording some captions and sentences, and
- elimination of one redundant described use, thus reducing the number of projected uses for this study to eighteen.

Different scales were chosen for the two ratings, experience (zero to four) and feasibility (zero to three), with the intention of aiding the responding teachers in making a clear distinction between

- their past experiences, based in the reality of the classroom/school situation, and
- the feasibility of these uses, not limited by 'temporal constraints such as adequate software or hardware resources.'

The second draft of the questionnaire was then submitted to seven of the eight teachers from the pilot stage for their responses to the content of the questionnaire and critique of its format. Five of these teachers returned the completed questionnaire and their written responses were included with those of the other teachers who responded verbally to the questionnaire.

Consideration of the critical comments received resulted in

- expanding or clarifying the descriptions of some of the uses,
- rewording the stems that invited comments about the 'programs used or considered', and
- integrating the 'description of use' and 'response' sections to form a small cohesive unit for each of the eighteen described uses.

The final draft of the questionnaire (Appendix A) was then ready for distribution to school jurisdictions and their teachers.

The Sample An early activity in the study was the search for teachers who were potential contributors to the study. As a result of informal discussions and inquiries at meetings and conferences, a group of teachers were identified to whom it would probably be worthwhile to send a questionnaire.

Correspondence with eighteen school jurisdictions in the Province of Alberta, extending an invitation for their science teachers to participate in this survey, resulted in the naming of seventy-eight teachers from local education regions ranging in size from a 5228-teacher urban district to a 18-teacher private school (Appendix F). Three of the teachers declined or were unable to participate. The remaining seventy-five teachers were sent a copy of the questionnaire (Appendix F) and a covering letter (Appendix

G).

Questionnaire responses were subsequently received from fifty of the seventy five teachers remaining in the study for a return rate of 67 %. The distribution of the respondent teachers by grade division and size of school jurisdiction indicates that most (60 %) of the teachers in the study taught in secondary schools or in large urban School Districts (Table 2).

The teachers who responded to the questionnaire, and from whose comments were drawn the observations that are detailed in the next chapter, probably form a select group of teachers:

- they were professional acquaintances of the researcher or were nominated by their employing school jurisdiction as being active in their use of computers,
- they were among the 67 % of the teacher contacts who had returned the questionnaire, and
- they had freely chosen to make the statements from which the issues and topics were derived.

A sample with these characteristics may be expected to affect the reliability of the study:

- The fact that the teachers were recommended for inclusion in this study would indicate that they had established a reputation for worthiness as a computer-using-science-teacher with the agency or person who nominated them.
- The completion by 67 % of the teachers of a questionnaire (that the pilot teachers had indicated would require more

Table 2

Distribution of Teachers Responding to the Questionnaire by Grade Division and Size of School Jurisdiction (Reported as Percentage of Sample) (N = 50)

Size of School Jurisdiction	School Grade Division E	 E-J	 J	 J-S	 S	Total
2501 - 5500 Teachers	6	2	14	2	36	60
251 - 2500 Teachers	-	-	2	2	16	20
0 - 250 Teachers	4	2	2	4	8	20
Total	10	4	18	8	60	100

Note: E = Elementary, J = Junior High, S = Senior High than one hour for completion) effectively brought into the study only those teachers who had a high level of perseverance and interest in contributing to the study. This persistence, could be a factor relating to their status as a practicing science teacher who had succeeded in integrating computers in to the curriculum but that is beyond the scope of this study.

- The last characteristic, by itself, could reduce the generalizability of the results by the selective or accidental omission of information. On the other hand, this was the one area where comments could be, and were, made concerning issues significant to the goal and process of the study.

Analysis of the Main Stage Questionnaire Results The first step in the analysis of the responses to the questionnaire was the assembling of comments from all teachers according to the several categories of use (Appendix B). This collection allowed the identification of three types of information:

- the inventory of programs that had been used by the respondent teachers,
- the issues and concerns of the individual respondents to be addressed during the interviews, and
- the tally and statistics of the levels of experience and feasibility of each use of computers by the respondents.

The inventory of programs was used to give the researcher a familiarity with the computer programs likely to be referred to in the interviews to follow. Notwithstanding the wealth of information which was available in the responses to the questionnaire and which is summarized in the next chapter, the major purposes of the questionnaire included

- gaining information to enable the construction of the interview questions for the main stage and
- the facilitation of the selection of potential interviewees.

Five major categories of knowledge about computer use and their associated sub-topics for teachers learning to use a computer in teaching science were identified in the responses to the questionnaire:

- fundamental operating and programming knowledge,
- hardware and perpipherals that are needed,
- software or courseware that is used,
- implementation or application in the classroom/school, and
- impact on the teacher.

Each is elaborated in the next chapter. Within each of the five categories of knowledge, questions were devised which encompassed most of the concerns expressed by the teachers surveyed (Appendix H). In addition, each interviewee was asked to suggest other learning needs of special significance.

The process of selection of the interviewees was aided by the construction of a matrix of information from the questionnaire. The purpose of the matrix of users and uses was to give a compact display of criteria that would be available for the later selection process. For this purpose, a grid was constructed (Appendix I), its structure formed by columns for each of the eighteen described uses and two 'other comments' sections and rows for each of the fifty respondents to the questionnaire. (The 'other comments' section of Evaluation Phase was not included in the table because of the general nature of the comments made there and limitations on the physical dimensions of the printed matrix.) Into each of the 1000 cells thus formed, a maximum of two symbols were placed which denoted criteria by which the selection of interviewees would be made.

Because the ability of a teacher to contribute to the study was considered to be dependent, in part, on both the teacher's level of experience with and range of vision of possibilities for each of the eighteen uses, the simple arithmetic sum of the indicated levels of experience and feasibility was selected as the numeric descriptor for each user/use cell. The process of selecting potential interviewees for each use included criteria, such as

- this self-reported level of present and future interest for the use,
- the relative (ranking) level of interest that other

teachers had indicated for the uses, and
- the nature of the specific application, as described in the comments.

A second, alphabetic descriptor was chosen that would clarify the nature of each active user/use combination. Perusal of the responses made by the teachers suggested that each user was commenting on

"A" - specific educational applications,
"a" - general educational applications, or
"o" - non-educational applications

and, therefore, the designated letter was chosen to indicate each of these possibilities.

The nature of some comments indicated a possibility that some misunderstanding might have existed about the interpretation of the description of each use. For example, several references to marks maintenance programs in the teacher's responses to Instructional Management applications raised the possibility of an imprecise description of this use. To indicate that the interviewer should clarify any misunderstandings about the nature of the respondent's actual use, a flag, < or >, was used to mark such uses for later possible realignment of responses.

Tabulation of Responses for Each Use in the Questionnaire

Because the learning needs of teachers might have different dimensions for each use, it was proposed that a profile of 'What a teacher needs to know to use a computer in science teaching' would best be drawn by accumulating comments by all of the teachers under each of the eighteen uses and the three 'other comments' sections. A computer text file was opened for each use and, as the questionnaires were returned to the researcher, the

- degree and type of experience, potential for further use,
- description of programs used and considered, and
- other comments were entered under the identifier for that responding teacher (Appendix B).

The collection of responses across all participating teachers facilitated

- the establishment of levels of activity and feasibility across all teachers participating in the study for each of the described uses,
- the development of a repertoire of computer programs used by the science teachers (Appendix C),
- the identification of issues which could be explored in the interviews and that were significant to the study of each use.

The indicated levels of experience and feasibility of each use for all respondents were tallied as the literal responses were recorded. For example, the tally of responses for "Test Records and Determination of Course Marks" for all fifty completed questionnaires have been extracted from the responses in Appendix B and are shown in Table 3. The responses to this use indicate that ten of the

Table 3

Levels of Experience and Feasibility for Respondents to a Sample Use of Computers, "Test Records and Determination of Course Mark"

Level	Number of Teachers Responding 0	1	2	3	4	Total
Experience	10	10	6	16	8	50
Feasibility	1	4	5	33	-	43

Notes: 1. The median of 50 teachers is 25. This score is at the number 2 (moderate) level of experience.
2. The median of 43 teachers is 22. This score is at the number 3 (very interested in and will be personally attempting to implement this use of computers) level of feasibility.

fifty teachers (20 %) did not use the computer for this purpose but only one of the forty-three respondents who described the feasibility of this use (2 %) did not see it as feasible.

For the purpose of exploratory analysis of the data to determine the central tendency and spread of the indicated levels, the median, 25 percentile (lower quartile), and 75 percentile (upper quartile) level of experience and feasibility for all respondents were noted for each of the eighteen described uses (Table 4). For example, the central half of the respondents to the proposed use of computers for "Test Records and Determination of Course Mark" had made 1 (little), 2 (moderate), or 3 (considerable) use of the computer with a median use of 2 (moderate. The top three-quarters of all respondents to the feasibility of this use were at a level of 3 ("very interested in and will be personally attempting to implement this use of computers". (Questionnaire 'Guidelines for Reponses', Appendix A).

Because the scales used for the experience and feasibility have neither the same dimensions nor equivalent descriptors, (note 'Guidelines for Responses' in the Questionnaire, Appendix A,) a comparision between the levels of these past and future perspectives on each use is not valid.

As the questionaires were returned, then, the information from the teachers was compacted according to the criteria described above and was rendered into a form which

Table 4

Distribution of Teachers in Described Uses of Computers by Levels of Experience and Levels of Feasibility (N = 50)

Computer Uses in Science Teaching	Level of Experience					Level of Feasibility			
	0	1	2	3	4	0	1	2	3
Phase I:									
Curriculum Planning and Materials Preparation	x	X	x	x				x	X
Professional Development	X						x	X	x
Communication between Schools and/or Teachers	X						x	X	x
Library Applications	X							X	
Instructional Management Applications	x	X	x					X	x
Phase II:									
Problem-Solving	X	x						X	x
Simulation	x	X	x					X	x
Tutorial	x	X					x	X	x
Gaming	X	x					X	x	
Drill and Practice	x	X	x				x	X	x
Electronic Chalkboard/Calculator	X	x					x	X	
Laboratory Instrumentation	X						x	X	x
Phase III:									
Test Production	x	x	X	x				x	X
Test Scoring	X	x						X	x
Test Records		x	X	x					X
Test Item Analysis	X	x					x	X	x
Correlation of Marks and Analysis of Trends	X						x	X	
Career Guidance	X	x					X	x	

Note: X denotes median level,
x denotes upper and lower quartile levels (if different than indicated integer median level.)

benefitted the conducting of the interview and the building of the information base for the study.

The Interview Procedure

The Purpose The purpose of the interview was to get in-depth information from selected science teachers who, on the basis of their experiences, described the knowledge and/or skills that would be required by a teacher who intended using a computer for specific applications in science teaching.

The Interview Questions The pilot stage indicated the value of a schedule of questions for giving direction to the interview and for giving the interviewer specific prompts to which the teacher interviewee could respond. The pilot stage had also determined that following the exact order and wording of the questions resulted in a stilted performance which both restrained the flow of information by the pilot teacher and also resulted in repetition where the teacher had already covered a specific topic of a question in a response to a previous question. It was therefore determined that a schedule of questions would be used during the interview but that latitude in wording and order during the interview would be desirable. The schedule of questions is presented in Appendix H.

The Sample Size of Interviewees To the extent that the respondents to the questionnaire and the interviewees could contribute, the goal of the study was to determine the learning objectives and knowledge content for each of the described uses. To create a reliable description of what a teacher needs to know, it was estimated that statements from a minimum of three teachers were needed for each of the eighteen uses. A trial interview during the eighth week of the main study indicated that two or three uses could be thoroughly described in the time allowed for the interview with each teacher. Hence, up to twenty-seven separate interviews were considered necessary to achieve the goal of an adequate description for each use. This requirement assumed that all teachers were able to make knowledgeable statements on at least two uses, that a minimum of three teachers could be found to contribute to each use, and that the right combination of experienced teachers and uses could be found to mesh the resources (teachers,) the limitations (time,) and the needs (descriptions) of the study.

The Selection of Teacher Interviewees The selection of specific teachers to be approached for an interview was influenced by several factors:

- an upper limit of about thirty teachers could be interviewed during the time period available for the study,

- most teachers were selected for a possible interview when neither the total number nor the nature of the potential teacher contacts were known, and
- a considerable disparity in the number of possible contacts in each use modulated the potential of specific teachers for the study. The selection of teachers was determined by both the need of the study to adequately describe weak areas as well as the desirability of capitalizing on the strengths of the teachers.

Within the limitations described above, the matrix of users/uses and the open comments were searched for potential interviewees according to the following general pattern:

- the three teachers who appeared most able to contribute to the knowledge base that was to be formed were identified for each use,
- five other teachers who had a potential to make a significant contribution to each use were identified,
- for each teacher-user, two uses which appeared to be that teacher's major thrusts in computer usage were noted,
- the chart was scanned to identify combinations of users/uses that would offer each interviewee the chance to speak about one of his/her major interests as well as two other uses in which the teacher had strength.

As the interviewees were chosen, they were invited by telephone to continue with the interview stage of the study. All teachers who were so selected and contacted accepted the invitation. In most cases, a letter of confirmation

(Appendix G) and a copy of the schedule of questions (Appendix H) was mailed to the teacher with the intention that the teacher might have an opportunity to peruse the issues and topics embedded in the questions before the interview. This precursor to the interview was considered important for the success of the interview,

- enabling the teacher to be aware of the focus of the interview and
- promoting some thought about the question and the teacher's possibly rehearsed answer.

Comments by the teachers during the prelude to the interview indicated varying degrees of preview of this precursor to the interview.

The Interviews The requirement for up to twenty-seven after-school interviews indicated that seven weeks of interviewing would be needed. (Few of the teachers for the pilot and main study were able to grant Friday after-school interviews.) In the eighteen week period available for the study, interviews were thus planned for weeks numbered twelve through eighteen (Table 5).

In practice, some interviews were granted during extended lunch-hour breaks and at dinner, evening, and at Saturday visits in the homes of the teachers instead of the planned after-school meetings. Because, at the planning stage in the tenth week of the main stage, most of the potential contacts appeared to be in the Edmonton area, only

Table 5

Number of Contacts with Teachers during the Main Stage by Week of Study and Type of Activity for Questionnaire and Interview

Number of Week	Type of Research Activity				
	Approval by School		Questionnaire		Interview
	Requested	Granted	Mailed	Received	
(Pilot	8	8	7	5	8)
1	29				
2	15				
3	2	14	13		
4	-	28	17	4	
5	-	6	10	6	
6	1	6	8	9	
7		1	2	9	
8		-	-	1	1
9		19	19	2	-
10		-	-	5	-
11		1	-	1	-
12			1	4	4
13				1	2
14				-	6
15				-	7
16				-	7
17				2	2
18				1	5
Total of Teachers	47	75	70	45	42

Notes: 1. The five Questionnaires and Critiques from the Pilot Teachers prior to the Main Stage are not included in either this weekly schedule or the totalled number of contacts shown.

2. Mailing of the final draft of the questionnaire to two Pilot teachers who did not respond to the second draft of the questionnaire are included in the weekly schedule and the number of contacts.

weeks numbered twelve, fifteen, and eighteen were reserved for interviews in the less well represented metropolitan Calgary and one week for northern Alberta.

Of the thirty teachers who had completed a questionnaire and were interviewed during the study, three granted a second, follow-up interview to clarify issues raised or overlooked during the initial contact. Because few of the science teachers contacted had experience with Instructional Management Applications of computers, an additional half-hour interview for this use was conducted with a Mathematics teacher who was introduced to the researcher as a knowledgable expert in this use of computers by one of the science teachers in the study who taught in the same school. The Mathematics teacher did not complete a questionnaire but data from the interview is included, where relevant, amongst that from the science teachers.

Two of the thirty one teachers interviewed taught in Grande Prairie and, because of the travel distance and tight time schedule involved, the interview with these teachers was conducted by the researcher's advisor who was in that area on other business. The advisor was briefed by the researcher on the significance of these contacts to the main study and was given oral and written instructions on points to consider in the interview. The advisor-interviewer was also given audiotapes on which the researcher had recorded two previous interviews in the study which would promote the emulation of the format used in the other interview of the study. The advisor was considered capable of acting as an agent for conducting these interviews because of these preparations and because he was concurrently conducting a study on another topic using a similar methodology.

Summary The study drew information from three sources: from practicing science teachers who were using computers in science instruction, from the current research literature, and from the researcher's own professional experiences. The part of the study involving science teachers was conducted in two stages: the preliminary pilot stage in which the instruments and the methodology were refined and the main stage in which nominated teachers responded to a questionnaire of computer uses and, if selected, contributed their observations in a structured interview. The results of the questionnaire and interviews are presented in the following chapters.

CHAPTER IV

THE DATA ON COMPUTER USE FROM THE TEACHERS

The results of the study on computer use by science teachers are presented in two major sections: a summary of the written responses to the questionnaire (Appendix A) and the statements made during the interviews. In the latter section, the findings from the pilot interviews have, where they relate to the description of the use, been combined with those from the main interviews.

Teacher Responses to the Questionnaire

The completed questionnaires, as they were returned, were identified by a sequential number to encourage objective evaluation of the comments written on the questionnaire. The responses were then accumulated in three tables: a collection of literal responses, both formatted and free, for each of the uses (Appendix B), a table listing the name and application of software programs that the participating teachers used (Appendix C), and a grid showing the level and nature of interest of each participating teacher and use (Appendix I). The collection of literal responses was intended to provide depth of coverage for each area of computer use. The table of software programs was used by the researcher for background knowledge during the subsequent interviews. The grid of users, uses, and usage was constructed primarily to facilitate selection of possible interviewees and was described in the previous chapter.

Levels of Teacher Judgement of Experience and Feasibility

Comparision of the levels of experience amongst the uses indicates that, for the teachers who returned the questionnaire,

a) the largest quartile-to-quartile range of level of experience was in the use of the computer for
  - Curriculum Planning and Materials Preparation and
  - Test Production,

b) the highest median level of experience with uses of computers was in Phase III, Testing and Evaluating, specifically
  - Test Production and
  - Test Records,

c) there were five uses of computers where the median level of experience was very low, viz.,
  - Professional Development,
  - Communication between Schools and/or Teachers,
  - Library Applications,
  - Laboratory Instrumentation, and
  - Correlation of Marks and Analysis of Trends, and

d) there were no uses of computers where the teachers surveyed had reached 'saturation' in their level of experience with that use, i.e., at least 3/4 of the teachers were at level 4.

Examination of these comparisons reveals some implications for the selection of interviewees for the main stage of the study, viz.,

1) priority for determining potential interviewees for the study-at-large would be given to those teachers who indicate an acquaintance with the five areas wherein there was an generally negligible level of experience among the respondents - note c) above - and
2) each teacher may be selected for interview in the areas where a generally high level of experience was noted - see b) above - according to special aspects of the implementation by the teacher, e.g., programs used or other comments offered or other needs of the study.

Other implications, primarily for inservice considerations, may be derived from observations a) and d) above but that is an area beyond the scope of this study.

Comparisons of the median levels of feasibility of the described uses of computers suggests that

a) three uses of computers were highly endorsed by the teachers,
   - Curriculum Planning and Materials Preparation,
   - Test Production, and
   - Test Records,
b) two areas of use are not generally likely to experience

high levels of activity,

- Gaming and
- Career Guidance.

Inferences that may be derived from these observations are that

1) the areas of high feasibility - note a) above - are also areas where the general level of experience is also high (possibly because uses would be regarded as feasible, or 'approved,' by teachers who were currently active in that use,)
2) the low attraction of Gaming - note b) above - may reflect a 'back-lash' to the possible arcade origin of microcomputer activity, and
3) Career Guidance - note b) above - may be perceived by the science teachers as being sited exclusively within the domain of the school counsellor. (At an earlier stage of the study, while considering the removal of this application from the roster of uses of computers by science teachers, it was decided to retain this use in the study and allow the results to validate this use by science teachers.)

The Programs that were Used

In the written descriptions of their usage of computers, most of the teachers included the names or descriptions of programs that they had used. Most of the programs were purchased or available on the commercial market - relatively few were designed or programmed by the teacher-user. The programs may also be regarded according to the extent of their versatility at performing a range of functions. Several types of programs were usually suitable for only one purpose, e.g., marks management programs used for Test Records. Others were found to be employed for more than one use, e.g., word processing programs used for Curriculum Materials Preparation and for Test Production. The programs are thus described, at this stage, either according to their general capabilities or for the specific uses to which they have been applied. (It will be assumed, at this stage of the study, that all programs with similar general capabilities are equivalent - any special features of specific programs will be determined during interviews with teacher-users.) A classification scheme for the programs that the teachers reported they were using was inferred from the use that was supported by the computer program or from the context of the solicited comments. The programs that were named by the teachers are grouped according to three characteristics: firstly, those programs which generally function to support teaching activities, secondly, programs used directly in the teaching/learning phase and for which the commercial source of the program was indicated; and lastly, the remaining programs, from unknown sources, listed according to the subject content area that was serviced (Appendix C.) There were also many unnamed programs that were most frequently described by the specific concept or function served.

The Analysis of Free Responses

The free comments of the teachers to the uses in the questionnaire were examined for statements that indicated the concerns of the teachers relative to the main question of the study. In this search to identify issues to examine during the interviews, five main areas emerged as being of some concern to the respondents, whose identity is indicated by the number in brackets that follows the quotation.

1. Operating and Programming The admission that

> I have just acquired a Gutenberg Jr. and in the process of learning to use it [#20]

hints at the dual tasks of selection and familiarization faced by intended users of computers.

Occasionally, the concern of the respondent was a sweeping

> there seem to be many areas I know nothing about [#29]

or, perhaps, a more specific

> One of the problems we've encountered is that no one seems to know anything about interfaces for lab equipment. Eventually, I hope this will be rectified [#35.]

A teacher who had apparently overcome the first hurdle of computer literacy offered the advice that Test Records and Determination of Course Marks

> is an excellent mechanism for introducing teachers to the computer. It is best to start with a menu-driven program and then advance to more complex programs like VISICALC [#15.]

Another teacher predicted that the use of computers for Testing and Evaluation, built on a foundation of familiar experiences before computers arrived at the school,

> will probably hit the schools before the previous two categories become a reality in that most teachers have used the services available [#04.]

2. Hardware and Peripherals When an individual or institution considers the introduction of any innovation into the daily routine, an early instrumental task is the appraisal of the balance between the effort or funds to be expended and the value to be received. The most frequently expressed concerns about the computer were the resources available for purchasing the equipment and the capability of the machine to perform the task for which it's purchase was intended.

Considering the use of the School Division's computer for Professional Development, one teacher observed,

> School not connected to central data bank via modem except for administrative records but not professional use. Will the costs justify or improve existing methods? [#04]

This same teacher recognized the benefits associated with Library Applications but cautioned,

> This aspect should speed up manual search considerably and space but terminal and production costs may prevent widespread use [#04.]

Another objected to tutorials on computers because

> Too expensive - need several rooms full of computers [#34.]

The ability of the computer to display adequate images was a concern expressed by teachers who saw, in an Electronic Chalkboard,

> A "smart" overhead? Great!! But: requires a large screen technology for in-class work [#21.]

Another, indicating that they planned to use Drill and Practice programs, echoed

> We've recently bought an Apple in our department and have built a cart with a large screen so that it can be used in individual classrooms [#35.]

Another's explanation for the computer not being used for Test Scoring like it could be was that it is

> Due to lack of appropriate software and inadequate automated system [#15.]

The ability of current state-of-the-art technology to fulfil the assigned role for Tutorials was explained as

> The programs I have seen so far are dreadfully boring because the computer has to go to the disk to fetch new problems. With larger memories in computers in future, there might be some possibilities here, but the micros at present are too slow [#14.]

3. Software and Courseware In many of the extensive comments made about the chararacteristics of the software programs that the teachers had used, the teachers elaborated on desirable and undesirable features of the programs. The concerns of the teachers about the software centered around

a) the `fit' of the program to the curriculum,

b) the ease of use for the novice user,

c) the requirements of the various teacher or student users,

d) the appropriateness of a computer program compared to other media, and

e) the appeal of the program to the students.

a) The compatibility of the program to the curriculum was noted by a teacher who had

> demonstrated titration simulation to indicate endpoint or equivalence but program used normal solutions so no longer used [#04]

and, with a Tutorial on Hydrocarbon Nomenclature, had

> Anticipated use for Chem 20 practice with nomenclature but found weaknesses in that iso-, neo-, and outdated usage was included [#04.]

b) Credits for the assistance available for novice users was given;

> The word processor program has a full range of easy to use commands plus on screen help pages. IBIS allows nonprogrammers to write tutorial or drill and practice lessons [#23.]

c) The relative abilities of various programs to meet the special requirements of Instructional Management applications were touted;

> Will use in scheduling, marks, attendance, etc., in administration extensively, the HARTS III system. At present using Chatauqua Systems which is cumbersome and time consuming besides does not do all functions required [#09,]

for use in Curriculum Planning and Materials Preparation,

> I have completed Physics 20 worksheets and tests. Diagrams are most difficult to handle [#09,]

for Production of Tests,

> In Chemistry, problem arises with use of capitals and subscripts [#09,]

and the recognition that, for Problem Solving applications,

> These types of things are extremely difficult to program so that a wide variety of input to the computer will be accepted. For instance - interaction between computer and student is not often allowed on an open-ended basis; he is forced to choose one of several given answers [#18]

which is echoed by the testimonial,

> I have not seen many tutorials, never mind quality tutorials, with provisional branches for individualized instruction [#35.]

d) Several comments were made about the requirement that programs be adaptable or accommodating of the needs of a variety of users as witnessed by the stated need, in Test Item Analysis, for

> Some general analyses which could be customized to my own specific needs [#18,]

the provision of Drill and Practice exercises that were

> Home-made-tailored to student requirements [#41,]

and, for Test Records and Determination of Course Marks, a

> Grades program which I have revised to suit my needs [#23.]

e) The teachers, with their experience of using a variety of media in their lessons, were quick to spot the potential and pitfalls of computer assisted learning using simulations;

> Totally agree with the seven examples used in explanatory notes as to what a computer could illustrate quickly and better than I could, e.g., sine waves. Better than films where only a portion is useful and where access to film [booking] is better. Depiction of motion is valuable characteristic, e.g., atoms bonding [#04]

and for Drill and Practice,

> Anything I have seen so far in this area has been supremely boring and does little the pencil and paper does not do more efficiently [#14.]

A few teachers expressed an unfavorable reaction to some programs, e.g., for Problem Solving,

> The vast majority of what I have seen in this area is not very interesting [#14]

and, using Tutorials,

> Students seem to get impatient and bored easily - although this is definitely a function of the program quality [#18]

and, for Production of Tests using templates,

> Most of these I have seen tend to be identical questions - but different numbers. A drag for many students [#18.]

4. Implementation of Application The teachers, whose main theatre of operations is the classroom, offered numerous comments about the actual use of the program in the intended setting of the classroom, laboratory, or school. Issues that were raised included

a) a heavy emphasis on the selection of the computer for appropriate activities,

b) an appreciation of the potential of the computer to expand the activities with which it is associated,

c) an awareness of options presented by the use of the computer program, and

d) followed by statements suggesting that a critical evaluation of one's philosophy of teaching with the aid of computers may be advisable.

a) A concern for the degree of match between the computer uses and nature of science that is emphasized seems to be a concern. For Tutorials in a Junior High School,

> The process approach we use does not lend itself to this type of science instruction. [#02,]

and, for the general usage of computer in science instruction,

> its use, in a good, activity ("hands-on") science program in the elementary school, will be limited to providing `back-up' services and `extension' work in what I feel will be rather limited units of study. [#49]

although a use is seen for Simulations in a Senior High School;

> They are developing some excellent simulations regarding the reading of scales, burets, etc., as well as simulations showing hydration, acid-base reactions, and diffusion and osmosis. These simulations are excellent and provide an excellent means for the development of process skills. [#35.]

b) The appropriateness of computers for Simulations in science evoked comments ranging from an enthusiastic

> In my opinion, this is one of the most beneficial areas of computer use. The ability to simulate ideas (free from practical limitations, i.e., friction in Physics) and the testing and manipulation of these ideas is a powerful tool. [#22,]

to a concern for overly neat electronic labs, especially Millikan's determination of the charge of an electron;

> I do not care very much for the Physics simulation. I have a philosophical problem with, for example, simulating the Millikan Experiment. This is probably the worst use of the computer in a Physics class. [#13,]

and

> If the real experiment can be done, i.e., oil drop method for electron charge, a simulation is not as good in representing the real "flavor" of the experiment. If the introduction of the computer will decrease the experimental activities done by students with real equipment, there will be no net improvement in science teaching. [#14]

and

> This is an exciting area to explore but is should be used with discretion. I would hate to see a student miss out on titrations just because the computer simulates it better. . . . Students miss much of the tacit dimension of science education when they don't actually handle the apparatus of scientific investigation. [#17.]

The dimension of appropriateness also extends to a concern for the grade level at which the uses are appropriate, e.g., for Laboratory Instrumentation,

> Useful possibility if programs available for this purpose. University and NAIT labs will probably get into this aspect before high school labs do so. Instrumentation fairly limited in high schools. [#04]

and

> Most labs at the high school level do not need the sophistication available with computers. Most labs are qualitative rather than quantitative. [#24]

and, for the utilization of a computer for Library Applications,

> For inventory of books, yes. At an elementary school level, I would prefer the students to use a card catalog. [#28.]

Disturbing perceptions of the use of programs that had a Gaming component surfaced;

> I dislike the notion of winning in a computer lesson - one of the worst I have seen . . . involved a math routine, the object of which was to answer a variety of questions and so "shoot down" the monster descending upon you. The group to which this was being

> demonstrated had an interesting reaction: they made deliberate errors to see what would happen when the "monster" got you! [#13]

and, on the matter of priorities,

> Most programs of this nature overemphasize the gaming at the expense of the content. [#28]

or the computer's presence as a comptetitor for the limited class time available,

> I don't think this is a good use of computer given the limited time to cover course content. [#33.]

b) The computers, introduced as an aid for instruction, appeared to promote a change in the classroom routines. For example, as an Electronic Chalkboard,

> For my Math 31 class, this is an important application. We often explore more complicated problems because of this. I have found that the micro has added an important dimension to this course in particular. [#17]

or, for Test Production,

> A boon! I use the word processor a great deal to prepare tests, quiz - to keep a bank of project topics, etc. . . . It it very useful to give pretest - posttest, and retests - something I was less willing to do before using the word processor. [#17]

or, for Test Records,

> An excellent use for computers. Allows many options too tedious when marks were computed using pencil and paper methods. [#18]

and yet this change of routine, even in trial form, was not always seen as beneficial;

> [I] have been involved in a University program where our computers linked up to their mainframe. This program allowed me and students to communicate with a professor (expert) there using a storage file bank. My questions stored there, and answered for the next day. It was very time consuming as it was set up. [#50.]

c) The flexibility of the computer for formatting data files apeared for Library Applications,

> Film classification on the basis of five fields (Title, number, topic, subject, and week of instruction. [#31])

and, for Test Production,

> Almost all my tests are stored on word processor disks. I don't use item banks. [#29.]

d) Lastly, a philosophy for utilization of the computer's potential that will embrace the concept of locus of control is indicated by one teacher's reaction to Instructional Management,

> This area certainly has potential as long as it does not become the total focus of education. A good education must cater to student interests and needs and not always force them into a mold. [#28,]

and will also support one's probing for an understanding of the reasons for the adoption,

> This would be a good application since it is an area generally neglected in the schools. Every school should have this computerized capability. [#22.]

5. Impact on the Teacher In addition to any responsibilities associated with the selection, purchase, and utilization of the several components necessary for computer assisted teaching, the teacher's personal and/or professional life is also affected by using the computers. The comments by respondees to the questionnaire illuminated the area of personal/professional impact on the teacher by revealing the following features;

a) the effect on the teacher's workload or preparation time,
b) the establishment of a level of confidence in the materials, and
c) the differing levels of acceptance by colleagues.

a) In the management of a limited and precious commodity, the teacher's preparatory time, one of many respondents indicated that using a computer for Test Production had

> Really made my job easier here. I have a data bank of about 200 questions in Grade 8 Science. [#26]

and that the teacher

> Can create test banks. This usage encourages modification of `faulty' test items with minimal effort. [#02.]

However, time may be reallocated rather than be saved, because, if a computer is used for Test Records, there will be

> No time saving but I like the print-outs. I give my science classes a report every 2-3 weeks - very motivating. [#26]

and, for Curriculum Planning and Materials Preparation by a teacher who is also a textbook author,

> This is a very satisfying use of the computer. It enables me to accumulate an interesting repetoire of materials and to update them on a continuous basis. I spend about 2 h per day working with the word processor - 4 days per week. [#17.]

The burden of time management becomes heavy, however, if a teacher decides to `go it alone,'

> I would like to see test banks available for. [chemistry], biology, and physics. Right now I'm doing my own input of questions but it is a waste of time.

> School boards or the Department of Education need to collect, organize, and develop test banks, problem generators, etc. [#35.]

b) A measure of the teacher's confidence in a program appears to be included in the requirement that a Test Production program be

> anything that I could trust - i.e. - well revised items and/or templates. [#21.]

c) The last personal or professional impact of computer use by a teacher appears to be the recognition by three teachers that, perhaps simplistically, teachers may be either considered as advocates of computer use,

> major flaw is incredible lack of "time to play." There are dozens of applications - but I can't see much happening in school, except where you have a teacher-fanatic present. [#21]

and

> My present involvement is in writing programs to deal with problems for self interest or to be used by specific teachers - I am still busy trying to convince my colleagues. [#44]

or viewed as passive observers of this change in the school milieu,

> Here are a few comments or problem areas in the use of computers in science education.
> 1. The reluctance of teachers to become literate and to use the computer. We have an APPLE IIe in our department that is used by myself and a few students. [#35.]

Teacher Statements during the Interviews

The thirty-four interviews with thirty-one teachers constituted about fifty hour of contact time between the teachers and the researcher during this main interview stage of the study and resulted in approximately 900 pages of transcripts of the teachers' statements.

The statements of the teachers were arranged, within each of the three phases of teaching activity, by the use of the computer within that phase and then by the five categories of knowledge (operation and programming, hardware and peripherals, software and courseware, implementation of application, and impact on teacher) being described.

Within the descriptions, brief quotes are given that illustrate the information that is being given.

Phase I: The Preparation for Teaching

This was the phase of teacher activity where the least number of potential interviewees who were using computers appeared according to the search criteria described previously. As a result, several uses were sparsely represented by practicing teachers.

One new category of use in this Phase, inventory management, had not been anticipated and is described in this chapter under Other Uses.

Curriculum Planning and Materials Preparation Activities of teachers in this section centered on the organization of curricular activities or the production of materials for student use. Programs used for the organization of activities ranged from using Visicalc for recording dates of achieving course objectives to a comprehensive Individualized Education Program (I.E.P.) for the evaluating a student's abilities and planning of a program to achieve specified behavioural objectives. Teachers who were producing materials were, generally, publishing teacher-authors.

The knowledge needed to operate the programs was as wide in its range and as varied in its content as were the programs used. The I.E.P. program was menu-driven and the spreadsheet and data-based programs (Visicalc, PFS File, and PFS Report) required recourse to the operating manuals for proper control of the myriad of functions. The word processing programs also ranged from the simplest Bank Street Writer with liberal screen prompts to the minimally structured Gutenberg.

Programming knowledge was negligible for both types of uses except for the necessity of entering into the program the command codes required for special print effects, such as underlining, superscripts and subscipts, boldfacing, etc. on designated printers.

Knowledge at differing levels is interpreted in this non-instructional use of computers as being between teacher-authors and teacher-users rather than students. The main expectation by the authors was that teachers-as-users would be able to employ the add/change/delete/insert functions of a word processor to achieve customization of curriculum materials to local preferences.

The brand and type of hardware that was used included Apple II+ and IIe or compatible computers, and Centronics 739, Epson CP80, and Star Electronics Gemini 10X printers. Knowledge was not identified for purchasers for planning activities excepting the desirability of having function keys for screen or print control (instead of using ESCape and CoNTRoL keys) but the interviewed teachers had clearly established their criteria for purchase for materials preparation including

a) the necessity of using super- and sub-scripts for printing formulas and ionic charges,
b) the desirability of being able to print non-alphabetic or numeric characters using a user-definable character set,
c) the desirability of being able to incorporate diagrams into their textual material,
d) the low cost of the equipment because most of the teachers had purchased the equipment from personal funds,
e) the ease of understanding the manual and the related operation of the program for novice users,
f) the fast operation of the computer or printer, and

g) the lack of portability of programs and data disks between computers produced by various manufacturers.

These teachers involved in curriculum activities, and several of whom had purchased their own equipment, were likely to have been involved with maintenance of the equipment. Problems that had been encountered were categorized as either service due to use or repair caused by component failure. The unit was frequently taken to the selling dealer for service but was increasingly being serviced by the teacher or the school district because of the cost, turn-around time, or lack of reserve equipment.

Problems included

a) cleaning and adjustment of the alignment or speed of the disk drives by the use of kits or utility programs,

b) replacement of a printhead cam or service for a pin of a dot matrix printer that did not imprint (including replacement of a microfuse), and

c) replacement of a stepping motor.

Maintenance was avoided by the use of a common domestic master power switch for the equipment rather than using the specialized switches mounted on the equipment.

Sources of information about the programs that were available for this use came from presentations or displays at Specialist Conferences, demonstrations by University personnel or practicing professionals, discussions with associates, and local dealers.

The actual programs that were used were purchased from local dealers (with revised versions purchased or exchanged with the original publisher) or, in some cases, were loaned to the teacher by an associate for evaluation.

The employment of the programs for curriculum planning was motivated by two concerns, a) the desire by the teacher to increase the quality of the teaching process by monitoring the attainment of course objectives or activities or, b) the mandating by legislative or fiscal bodies of systems for testing, evaluating, selecting objectives, setting goals, and monitoring progress of individual students. The interviewed teachers selected computers for this activity because of the ease of revision of the produced material.

The individual programs were selected for curriculum writing because they

a) had a level of complexity which was commensurate with the skill of the intended user, e.g., from Bank Street Writer for novices to Gutenberg for dedicated and experienced users,

b) offered a basic core of functions, e.g., add/change/insert/delete/search/replace,

c) were programs with which the user had already become familiar, and

d) were of low cost, a significant factor for personal finances,

e) were commonly available or produced files that were transferrable, and

f) had a screen display which was congruent with the printed page for ease in producing tables of data,

g) enabled printing options required by the user, e.g., underline, highlight, double-strike,

h) were flexible in their formatting of the textual material, and

i) incorporated a spelling checker option.

Criteria for evaluating the word processing programs were also dependent on the specific application, e.g., for Math or Science curriculum, the requirements of

a) the ability to draw and include graphics and diagrams in the text and

b) the ability to design and print non-alphabetic characters.

This use of computers was suggested, for one user, by the example of a University lecturer and, for an author, by the local school board's central science department and the experience with the Curriculum Resources Information Bank, (C.R.I.B.)

This use of the computer began, in all cases, with the entry of information into the program.

For the planning application, these entries included,

a) the course objectives from the provincial curriculum handbook or the units and topics from the texts, or

b) the results of standardized testing of students, the characteristics of the student's needs, and the locally developed behavioural objectives.

For curriculum preparation, entry of the raw text followed shortly behind familiarization with the program.

Difficulties encountered by the interviewed teachers with this use of computers included the budgetting of time to keep the information up-to-date following the initial entries, internalizing the operation of the computer program by summarizing essential commands, and coping with the difficulties associated with entering text in this unfamiliar medium.

The teachers most frequently referred to associates when they described the support that they had received with implementing the computer with this activity. The assistance that they received included the designing of non-alphabetic characters and advice on the operation of the program.

The primary limitation of the use of a computer for this activity was a recognition of the tendency of a teacher to spend extra time perfecting curriculum materials, a task made easier by word processing on the computer.

The role of the teacher who uses a computer for curriculum planning is, for the I.E.P. program, a reduction of time spent on clerical tasks and in meetings. Many effects were felt for the teacher who uses a computer for curriculum preparation, most notably a more creative orientation toward printed material, at the expense of greater outlay of time and money.

Other factors that would affect the entry into, or continuation of, this use of computers include

a) the benefits of keyboarding a computer instead of a typewriter,
b) having a good working knowledge of a similar computer program,
c) having a computer readily available at school or at home,
d) working with a few other teachers on a project,
e) provision of support staff trained to work with this medium.

Professional Development There were no teachers in the study who were experienced in using the computer for professional development. Because communication with other teachers or professional leaders was considered to be a component of this phase of a teacher's professional activities, respondents who had used their computer and a modem to communicate with other systems were considered to have a contribution to make here. The results in this section are based on two teachers who appeared to have sufficient background in this area to make a significant contribution to this study.

An operating knowledge of a modem with a computer was limited to knowing what functions a modem could enable, what systems could be accessed, and to respond to the menu of an accompanying program so as to contact a system and achieve these functions.

Programming knowledge, as such, was not required by users who had purchased a program that enabled operation of the modem. However, prior to the initial use, the program must be used to configure the modem to match the expected electronic communication protocol and thus the values of various parameters such as baud rate, parity, data bits, and stop bits must be known for the intended contact. Further, if the sending and receiving computers are not of the same type, key strokes that perform equivalent functions must be defined.

Because the computer/modem system may be used for a variety of activities, differing levels of computer literacy may be required by the teacher depending on the nature and complexity of the use to be made of the system.

The interviewed teachers had purchased their own equipment for communicating with other computers; similar equipment was expected to be purchased by the school for retrieval of test items from a central school district mainframe. One teacher was using a built-in Novation Cat in an Apple IIe with an Apple 80-column card and an Apple III monitor.

Characteristics of a modem/computer system to consider when purchasing include

a) the capability of the modem to operate at various speeds, usually 300 baud or 1200 baud,

b) the benefits of either a direct connection (telephone jack) modem or an acoustical modem into which a telephone handset is inserted,

c) the preference for a space-saving, built-in modem or an external unit which can be used with a variety of computers,

d) the preference for a modem that has the program built into its circuitry or a modem that uses a program stored on a disk,

e) the requirements for a complete system, possibly including a serial communications card,

f) the capability of the computer to display the full screen width transmitted up to 80 columns,

g) the presence of local repair facilities and access to back-up equipment, and

h) the presence and quality of after-sales in-service for the purchaser.

The teachers had had no difficulty with the communications hardware and had had only a disk drive that needed alignment by the dealer.

Information about specific programs, bulletin boards, and modems was gained by reading periodicals, books, and from other bulletin boards sponsored by local computer dealers.

The programs that operated the computer/modem system were purchased, as a package, along with the modem from local dealers.

The primary factors that determined the extent to which the teachers expanded their use of the modem for communication between computers was the financial cost for subscription or long-distance tolls incurred while accessing various data banks and bulletin boards and the time cost of learning to operate the system.

Criteria by which the quality of the modem's program was judged were primarily related to the ability of the program to perform various functions. Programs were expected, in order of decreasing significance, to

a) be controlled from a menu with screen prompts for entries,

b) be able to format the screen display to accommodate displays produced by various sources,

c) be able to dial out, download information from a system, print this information, and save the information in either binary or text files,

d) be able to leave messages on a bulletin board or send out files of information, and

e) be able to emulate various terminals.

The possibility of communication between computers was made apparent by observing contact between personnel at Universities in two provinces, by seeing an associate manage an investment portfolio by accessing a international data bank, and by advance notice of the intention of a school district to offer access to test questions that were stored on a data bank and that could be retrieved by a printer/terminal.

The first step to be taken, after installation of the hardware, is the configuring of the modem by entering the values of parameters that govern the electronic communication. This configuration may differ between various systems with which the teacher may communicate.

Difficulties encountered include the general poor quality of owner's manuals exhibiting a tendency to either be sparse or to overkill or the tendency of systems to establish operating procedures that are oriented to specific computers. Another problem encountered was the need for guided exploration of the operation of the program, solved by having a second telephone line installed for conversation between associates who were simultaneously attempting communication between computers.

Support systems included extensive referral to friends and requests for assistance from other bulletin board users. In general, personnel from local dealers were not helpful.

Assistance in using the modem was given in the form of practice in inter-computer communication, information to supplement the instructions give in the operator's manual, and the loan of alternate programs for control of the computer/modem.

The limitations perceived in the use of modems for communication were

a) the accessibility to the systems, including the financial load imposed by computer contact with various systems, and

b) the general lack of awareness of, or skill in using, the computer data banks as sources of information.

The role of consultant to others was one that had opened for the teachers who were experienced in inter-computer communication.

The likelihood of the teacher participating in professional development using a computer for communication is dependent on the teacher

a) developing a familiarity with a prototype of the type of program or modem available, thus building up a reservoir of knowledge about the operation of various systems,

b). knowing that a variety of sources of information exist, each with its particular financial and operating requirments,

c) being aware that different levels of operation of the system exist, each requiring different degrees of sophistication of knowledge, and for which different levels of assistance or inservicing are required,

d) having access to the equipment required for this activity.

Communication Between Schools and Teachers Because few teachers in the study had experience with electronic mail and none had experience with electronic transfer of student records, and in view of the relatively low potential expressed by teachers in their using computers for this purpose, the following description will identify only characteristics that are unique to elecronic mail between individuals and that are in addition to the description in the previous section on using a computer for professional development.

Operating knowledge required by the teacher would include entering any identification assigned by the central "mail box" facility to the teacher-user.

Hardware that is acceptable for this purpose must be able to synthesize and transmit those ASCII characters required by the central facility for executing specific functions.

The facility through which the electronic mail was processed was the Alberta Government Telephone's Envoy, in preference to the University of Alberta's M.T.S., because of the nature of the proposed contacts by the teacher that were possible and also because of the cost of the contract.

Special situations relating to implementing this use by the teacher were primarily in the area of signing-on other persons as sub-users under his contract, of assigning a monthly charge to these sub-users, and the restricting of these sub-users to specific files under his control.

The main impact on the teacher of this use was the ability to send the mail at any time of any day and for it to be instantly available to the addressee.

Library Applications Because none of the science teachers in the study were also responsible for the operation of the school library, the description of this use has been broadened to include situations where individual science teachers used a data based system for the management of various professional resources, including films, reference materials, department inventory, etc.

The staff member who operated a program for the management of library books in one school was a library technician; the details of the operation of this program were known only by a former teacher who had set up the program and the current library technician. The programs that were used by science teachers for their own resources were commercially available, menu-driven programs for which the user needed an understanding of the general framework within which the information was stored and a knowledge of the meaning and significance of the procedures offered. All sources indicated a knowledge of programming, as such, was not required except within the context of being able to formulate a template for recorded data. Because the programs were used only by the teachers in the scenarios described, information about requirements for use by students was not available.

Hardware used by the teachers interviewed was known to be of two types, a Radio Shack TRS-80 purchased originally for a business application and Apple II+ and IIe versions with 80-column display. Monochromatic monitors, dual 5.25 inch disk drives and dot matrix printers were used.

Features that make the machines desirable for this application include low cost of the computers and the programs and the availability of software for this application. A change from Apple II+ to IIe was necessary to achieve an 80-column display, increased memory, and improved keyboard.

The only maintenance required by these devices was the adjustment of a disk drive by a dealer.

The interviewed teachers learned about these data-based programs by talking to associates, reading periodicals, e.g., Personal Software, and previewing programs available from commercial dealers. The actual programs used were loaned by friends for previewing, were retained for personal use by the teachers when other applications were finished, and were received as part of a software package upon the initial purchase of the computer.

The intention of the teachers to develop these computer-based data-management systems for their resources was dependent on a) the ability of the system to perform `normal' teacher tasks more efficiently than previously achieved by other, less technical means, and b) a prediction of the benefits to be accrued in light of the time required to achieve these benefits. Prior to purchasing or developing a specific system, the teacher needed to clarify their expectations of the system and its capacity to fulfull these expectations.

Characteristics of programs that achieved these expecations are that

a) data files created by one program should be able to be used by other programs in use by the teacher or by significant associates of the teacher for the purpose of mutual benefit by exchange of information or to avoid "orphaning" files created by the changing of computers or programs,

b) entry, search, and printing of data should be easy, rapid, flexible, and fulfill the tasks defined by the user,

c) the manuals for the programs be models of good communication to novice users.

Most of the teachers interviewed were using this technique of resource management because of their active exploration of the possibilities within the computer domain; the program were received as gifts at Christmas or were part of a computer purchase package or had been used in a similar capacity in a business environment.

The initial task, after becoming familiar with the operation of the program, was to define the number and length of major heading and sub-headings to expedite retrieval of the stored information, followed by the ongoing task of entering the information to be accessed.

Difficulties experienced by the teachers included a) the inadequacy of the poorly-written manuals to properly guide the user (solved by consulting friends who had the same program,) b) optimizing the number of major headings to allow for expansion and to decrease the time required for search, and c) confronting the incompatibility between older versions of programs with later models of the computers.

Support systems for the teachers who had difficulties were, firstly, the dealer from whom the machine or program had been purchased and, secondly, acquaintances of the teachers. Specific assistance rendered included adjustment of electrical components and reconciliation of computer/program incompatibilities by the dealers and assistance by aquaintances in the operation of the program.

The prime limitation of this use of computers to good teaching practice was the determining of the legitimacy of the use.

> Are you doing this to save time and to make the computer do work that ordinarily you would normally do? . . . The only thing that goes in is that stuff that I am almost certain I am going to derive benefit from having it on the computer, because it takes time to put it in there. . . . I haven't got the time to play around. . . . I think that the things that I put in now are the things that used to give great difficulty in doing - still give me difficulty, but at least getting much more help within the computer than I used to before. [#46:836]

No new roles were identified by the teachers who used this computer-based resource management system as a replacement for pencil and paper techniques, except for resolving the question of "working or playing" with the computer.

The probability of the teachers using the computer for the uses described above was primarily dependent on the familiarity that they had with the program.

> I use it as much as I do because I started with it and you become familiar with it and you keep on using it. [#46:250]

Instructional Management The integration of several uses identified elsewhere in this chapter are integrated when teachers use a computer for Instructional Management. Under this general title, teachers used computers in two contexts; institutional management, being the administration of the students in a school, and instructional management, relating to the learning activities for individuals or groups of students in a class or subject. Because the first use is usually the responsibility of an assistant principal and the second context is the one which a science teacher would most probably meet, the description that follows is based on the interviews with two teachers from one school who were active in Computer Managed Learning.

The knowledge required to operate the C.M.L. system was varied, depending on the particular function that was being employed, i.e., as a student drawing assignments or work sheets or as a teacher using a pre-defined course map and questions, revising parameters, designing a course map, or constructing or editing test questions. For both groups, the program was menu-driven with help available in a student's one page guide or a teacher's looseleaf Users' Guide.

Knowledge of programming was not required but an aquaintance with file management procedures that are part of the authoring language was considered necessary.

The sequence of sign-on procedures for the students and teachers differed, as did the number of windows of security that were traversed to reach the intended program.

The hardware that was used at the school was a LA-36 Decwriter teletype terminal to a central, district mainframe.

The costs and benefits of using a teletypewriter or a keyboard and monitor need to be considered for this application. The teletype consumed considerable quantities of paper for printing tests, in addition to other purposes for which a monitor was being considered, such as students writing computer programs or supplying answers to a previously printed test and teachers engaged in managerial tasks with the program.

Contracted technicians were called for all maintenance of the teletypewriter, generally restricted to replacing the head drive motor for several machines.

The program used by the computer was developed by a local technical institute and was part of the C.M.L. package for the whole district.

The decision to implement computers for instructional management was made by the school adminstration as part of a continuing process of individualizing the progress of students, currently as a Personalized Educational Program (P.E.P.), and including features such as open-area school floor plan, development of unipacs, unstructured time periods, and testing on demand in a testing centre.

Criteria that were significant for the students and the teachers as users of the management program included

a) provision of a question bank for review, quiz, or testing of progress, objective marking of these questions, and recording of students achievement,

b) those features related to the nature of the assignments for the students including
   - flexibility of the pace and route for students with varying needs,
   - reporting, in an itemized summary, to the students their progress after quizzes,
   - provision for testing parameters, e.g., mastery level, routing after tests,
   - variable weighting of questions involving several process steps, and
   - provision for parallel tests of equivalent difficulty,

c) accessibility of all components of the system for revision by teachers.

The teachers had been invited by the school administration to participate in the implementation of computers for individualizing progress.

Implementation of this use of computers began with the system-wide writing and recording of test questions into a data bank and the simultaneous design of "course maps" for the sequential development and testing of concepts.

Difficulties encountered and resolved included

a) shaking down the bugs characteristic of innovations, e.g., erroneous descriptors, alpha-numeric I.D.s,

b) maintaining and re-establishing contact with the mainframe computer during school hours,

c) orienting the students to limitations of the media, e.g., notation for exponents, square root,

d) judgement by the teacher resulting from poor communication between the student and the computer, e.g., spelling errors, and

e) monitoring, and referring for discipline, nascent hackers.

The teachers received extensive support within their school district including the

a) secondment of other teachers to construct the initial structure and content of the C.M.L. program

b) inservicing of the teacher in workshops, courses, and seminars on concerns significant to the concept of individualized progress of students, e.g., learning styles, file management, test development, and

c) formation of interdisciplinary Personalized Education Program (P.E.P.) teams for each grade level for the exchange of new approaches and ideas.

Assistance available, in addition to that mentioned above, included print materials for operation of the computer by novice student and teacher users.

Using computers for this learning activity enhanced the ability of students to acquire the course content at their own pace but provision is needed for the development of process skills, the interaction of learners through discussion, and the social aspects of school. The teachers were also cognizant of the possibility of increased clerical workload through extensive contact with the computer.

The greatest role of the teacher in an computer managed learning environment is that of facilitator of the student learning; the student is working as an independent learner and is receiving instructions from a device with limited intelligence and thus will require aid. The teacher must be skilled in the processes of curriculum development and open to suggestions and is also a subject content expert, able to design course maps for controlling student progress. The C.M.L. teacher has access to more extended resources and thus requires judgement about their employment.

Factors that were part of the decision of the teacher to engage in this use of computers included the

a) provision of paraprofessionals to handle technical matters,

b) availability of an optimum number of computers,

c) ability of the teacher to modify the program parameters to match the learners,

d) involvement of the teacher in satisfying activities, and

e) opportunity for the teacher to apply knowledge previously gained.

> I did take a couple of courses at University but, in undergrad, you never realize how important some of these things actually could be. . . . You are doing it in a very theoretical way. When it comes to actually doing it, you are surprised that there is actually a practical application. [#51:272]

Phase I: Other Uses The only other pre-teaching use of computers that emerged during the interviews was the recording on a computer data-base of the materials on inventory of a science department. The teachers were using commercially or custom-prepared programs for recording stock levels to aid in purchasing supplies for the coming year.

The menu-driven programs operated parallel to the normal operational tasks of a laboratory aide of entry, inventorying, and re-ordering of materials. Prompts were given when entering data. Various options for handling this information were available.

No knowledge of programming or file management is required.

For both programs, setting up the operation required more knowledge and time than subsequently using the program to maintain stock levels. For one program, a teacher would need to categorize the chemicals on hand, according to their chemical properties, as organic acid, inorganic acid, base, oxidant, chlorate, nitrate, flammable solvent, or flammable solid. A typist would then be needed to enter name, date, and quantity of chemicals received or in inventory.

Hardware requirements included an Apple II system with disk drives and printer. The compatibility of control characters sent by the program and received by the printer for print effects should be verified. No significant history of maintenance existed for this use.

These data-based programs were similar in their operations of entering, selectively retrieving, and revising information. One particular program was developed under contract by a school district for use in its schools. What distinguishes this program is its philosophical foundation of segregating and color-labelling incompatible chemicals and dating all stock. Adoption of this program would be beneficial by a science department similarly oriented and that had access to a typist. Another program was used to gather restocking requirements from several schools. The program could then list these requirements by school or by supplier. Implicit criteria for both applications include the selective sorting of records by descriptive fields, the performance of mathematical operations on values entered, and the printing of formatted information.

The concept of the categorization of the chemicals was derived from an article in a professional periodical that resulted from the preparation of a hazardous chemical guide for the province. In both cases, the teacher voluntarily participated in the development of the application.

The initial actions to be taken were to identify all materials to be stocked and to record them in the data bank of the program. A district with a central purchasing authority could reduce individual typing time by recording names and catalog numbers in the data file or on checklists of items required.

Limitations of screen display suggested chemicals be accessed by name and cross reference names instead of chemical formula. Access time for loading the program from the disk suggested a hard copy of all chemicals for individual staff members and hard copies of each category of chemicals for inventory checks would be most practical. In general, the benefits of computerizing the inventory increased as the number of items or related organizations increased.

Classifying the materials could be aided by referring to a color-coding system employed by chemical supply houses or to lists prepared for common activities. To enable operation by teachers, formats used were closely related to other curriculum materials used by the teachers. Manuals were available and, in the absence of close supervision, were required the first few times the programs were used. Any limitation of this program on human resources in a school is based on the relative efficiency of the program to maintain an adequate level of stock better than other systems.

Roles for the science teacher would be categorizing of the chemicals in a school storeroom and, in the absence of clerical assistance, typing of entries for stock movement, or notifying a computer operator of items to be replenished.

A science department may adopt programs of this type for faster identification of old, dated stock or of short-stocked items, for an easily up-dated list of chemicals, by selected categories or in total, or for maintaining an adequate level of consumable items.

Phase II: The Teaching/Learning Act

In this essential phase of teacher and student activity, the greatest number of teachers indicated some experience (level > 0) with the uses of computers that were presented in the questionnaire (with 152 teacher-uses indicated). For some of the more well-represented uses, the selection criteria employed to pick between good, competitive represented users were the comments appearing on the teachers' questionnaire.

There were some uses, e.g., Electronic Chalkboard and Laboratory Instrumentation, which were sparsely represented and selection was based on other criteria, including ability to contribute statements about knowledge needed for other uses of computers.

Problem Solving Three teachers had students who had used a computer for problem solving, that is, to test an understanding of a system in science by constructing a model of the system and then testing the model for correlation with other ways of knowing. Ten other teachers contributed their observations on specific dimensions of this use of computers.

The computer is well suited for modelling a physical system.

> Then I get them to . . . give me their series of steps, the algorithm, to solve that problem in REM statements and then I get them to write it in structured program approach which is all subroutines interactive. [#39:1175]

The state-of-the-art for the science teacher whose students were `solving problems' required that they have a good understanding of instructional design and, according the experience of the teachers, varying amounts of knowledge about programming.

> I had to have had enough experience on the computer to know what kind of displays I could expect on the screen. [#34:21.1]

A computer language or program must be available for the student to use during the problem-solving activity. A teacher of gifted elementary children had used LOGO, Rocky's Boots, and Bank Street Writer in problem-solving situations.

The context of these activities was not science, as such, but as challenges for the students. BASIC language was tried and rejected as not suitable.

> Because the BASIC language is so specific-, you have got to have the syntax right-, you have to have the commas in the right place. But they were being bogged down with such trivia so it wasn't helping them. [#50:7.2]

The secondary science students needed to be proficient at programming in a higher level language, e.g., BASIC, or machine language.

> They can write it either in BASIC or machine language or Pascal and I've had students do some hybrid programs. For instance, the library sorting program for overdue library books, [two students] wrote the actual sorting technique in machine language and wrote the rest in BASIC and put it together. [#39:1175]

The teacher can learn the skills needed by using references and various teaching experiences.

> I think most teachers already have the educational experience necessary to know how you are going to have this thing set out. If the teacher has had enough just curriculum materials experience and teaching experience, he has enough knowledge to say, "Okay, I don't like the way that is being asked. Can you put it in this other way?" . . . If you have used a couple of programs, it would be helpful because you know how these kinds of things can be asked on the screen. [#34:21.6]

The students can learn the programming skills at home, at school, or by using models of routines in programs that are available.

> I would say that probably a lot of it was from programs that they had seen-, routines that they had seen, picked up from friends, whatever. They did not create all of these things themselves, I am sure. They found out where these things were found, went into the

> program and looked at how these people had done this and probably, in a large part, copied a lot of the ideas that people had used in terms of displays, although their final thing was unique to themselves. [#34:27.2]

The hardware that was used by the students were Apple and Sinclair microcomputers and Centronics, Apple, Epson, and CItoh printers. The Apple hardware were used for several and various purposes in the science departments. Various features made the Sinclair suitable for student programming in problem-solving,

> In addition to price, I think the major advantage of the Sinclair computer is that all the commands, all the key words, are single key entry so that if you want so say "Print", you just press the "P" key. . . . All of the commands are that way, all of the function keys are that way. . . . You don't ever have to type up a whole word. These students are not typing students so this was a distinct advantage for them. . . . It was small and it would run on your own home television. I used to let the kids take these things home for the weekends and holidays. [#33:778]

although some disadvantages were described.

> The main disadvantage to it . . . is that it is a membrane keyboard. For somebody who was a typist, that would slow them down a lot. . . . The main handicap of not having a disk is the speed of loading and saving; that is where you waste a lot of time. It takes a long time to load and save from a cassette. [#33:883]

Only one teacher in the survey had used the Sinclair; the isolation of this lone usage was ensured when distribution of the Timex Sinclair ZX-81 ceased.

> They are not available over the counter anymore . . . . The thing that I really went over there for was a printer and I was too late. [#33:942]

Maintenance of the Sinclair was limited to replacement of a computer, a memory pack, and a power supply.

Software programs were not available for the students to use during the construction of models of physical situations. The concept of sofware or courseware is interpreted, for this use of computers, as programs that the student will construct, rather than a program that will host the one that the student will develop.

Some of the students were given a sample program that served as a guide or model of the program that they were to construct.

> I gave them, initially, a program that was available . . . and said, "Well, here is something that the Federal Government has done but they calculated differently than we calculate it. Their calculations are a little bit beyond what I want to present in a Grade 11 course and therefore I would like you to maybe take this and modify this so that it would be all metric like we are using and units that we are using and do the calculations." . . . Even with some kids, I've asked them to fix up some of the MECC programs that we have in the school through ACCESS. [#34:19.]

In most other cases, the only assistance available from the teacher was the definition of the general problem and suggestions about user-related displays.

> I may come to the students and say, "Hey, I would really like to have a program like this and I know you're interested in this as well. Why don't you do this as your project?" For instance, in Physics 30, I like to have the students do three small projects per school year and have them relate to each of the major topic areas that we cover. . . . First term, I had them do a computer simulation of electric fields. In this last term, I had them do one on the Michelson-Morley experiment. [#17:530]

For the student, the subject material that was integrated into the construction of the complete program was drawn from the academic course content.

> [This program] was in lieu of his . . . major project which they do in Physics 20 where they are required to design a low-energy passive solar home that could be heated in Edmonton for $50 to $150 a year. So it is a project which lasts for over about a six week period. [#34:22.8]

For the teacher, the background that supported the scientific content of the programs came from literature research.

> I looked around in books and so on to find out how to do these kinds of calculations. . . . SWERP has a library. I can remember going over at one time and talking to the people over there that I know at SWERP and saying, "Now, how would you do this calculation?" and "How would this work out?" and so on and just keeping up on my reading as well. [#34:25.9]

The factors that determined the development of a computer program were

- the level of interest and ability of the problem-solving student,

> Most of them are pretty traditional; they'll do the paper or the experiment. But I try to encourage some, especially the ones I know aren't real achievers in the traditional realm but who, I do know, have an interest. But even then, surprisingly, sometimes they won't feel confident enough to maybe really explore their strengths or what I see as their strengths. They still go the traditional way. . . . I would be lucky to have 20% who would really be that adventurous. [#17:641]

- and the utility value of the program for later use by the class-at-large.

> There was a more immediate payoff in that I would teach them how to write programs to solve physics equations and that they would be able to do some of their homework using the programs that they had written and

> also that their classmates would be able to do some of their home assignments in regular class, desk work times, to do the same kind of-, get the same kind of benefits from the programs that they would write. [#33:697]

Evaluating the problem solving activity of the student involved, for most teachers, judging the worth of

- the activity itself,
- the program produced,

> He hasn't got documentation of how to save and how to load. The program runs well but he hasn't got the user information so now I've got to get after Greg and show him what I expect in user information so he develops a-. [#39:1175]

- the extent of correlation between the student's program and other programs or references,

> I was amazed that the model that I used when the students first did it-, and they did it by hand-, worked. out as close to what the predictions were of these very sophisticated models. . . . We compared, for instance, when the students completed their program as well, we compared the output from the Hot Can program to our program and they were within $10 to $50. . . . That is certainly close enough; I wasn't concerned with that kind of amount at all. [#34:26.5]

- and the suitability of the program for the end-user.

> You have to look at . . . whether it fits the objectives of the lesson, the content that you want to get across and the style of your teaching and the general sequencing of the material and the completeness. [#43:597]

Responsibilility for starting the problem-solving activity began, as usual, with

- the teacher soliciting the interest of the students,
- although some students later took the initiative.

> It is usually a combination of me being the initiator and the student being the initiator. I may come to students and say, "Hey, I would like to have a program like this and I know you're interested in this as well. Why don't you do this as your project?" . . . . I have had students come up with ideas, "I would like to do something on demonstrating the Newton quotient so that the kids will understand the idea of derivatives a little bit better." I had one student come up to me and suggest, "I would like to do integration and show Riemen sums-" . . . so it has been a bit of both. [#17:530]

The difficulties that were experienced and resolved by the students and the teachers were varied and included

- access to the equipment

> Some of those kids would come in at noon hour, some would come in after school on days that weren't the days that I was teaching this. . . . I used to let the kids take these things home for the weekends and holidays; I would just book them out like a library book. [#33:778]

- and the attempt to pattern the student's program on an available model.

> We first tried to use the TI-59 program and then we just kind of gave up on that idea and said "Fresh start." . . . . They took the thing away and looked at it and they came back and they said, "Well, really, we can't." It is almost like trying to translate the TI thing. It was in BASIC and everything but they decided to start over again. They came back within a week or so with this program which was really fantastic. [#34:19.]

There was no evidence of a formal support system for the teachers and any help received by the student was usually based on personal contacts by the teacher.

> In a couple of cases where I had problems with knowing how to help the kids in their program, I for instance, asked [a colleague] if he could help them out on that. I think, in a minor way, he did-, in terms of

programming skill. [#34:32.11]

No aspects of this use of computers were identified as being incongruent with good teaching practice.

There were several impacts on the role of the science teacher who offers problem solving on a computer to his/her students. The most frequently mentioned change was that the teacher must recognize

- the limitations of his/her own ability to know everything about all problems that will be identified;

> You don't have to be the expert to run these things; you have to know how to start them and know how to direct kids, but you don't have to have all the answers. Part of problem solving is that you can find the answers yourself. [#50:8.6]

- the need to tailor the task to challenge the student,

> So it was a kind of an interaction thing as well. Once I saw what these kids were capable of doing, then my ideas as to what they should be able to do kind of increased. You have to be kind of cognizant of where the kid's programming level is at. [#34:30.0]

- and also the requirements of the students for leadership and guidance.

> I think the thing that I might see . . . is the interpersonal skills required in terms of getting the students to do these kinds of things. . . . The job can become horrendously complex and over-bearing in a sense to the student . . . in terms of getting this thing done and getting it to a point where you want it. You have to, I think, be able to watch where the student is and I find, a lot of times, just back off-, . . . I think that is a pretty important thing for teachers to learn in terms of interacting with the students and recognizing that it is a different kind of problem solving by the students than, perhaps, we are used to-. Where there isn't a nice linear line to the answer-, not guided all the way and the student is going to have difficulty. . . . Going to become frustrated at certain points and times because the computer keeps doing what

> they are telling it to do and not doing what they want it to do. [#34:33.11]

Simulation - Modelling Inspection of the responses to the questionnaire indicated that two distinctly different applications of simulation were possible; the conventional presentation of a model of a physical system where the student observes changes in the responding variables and a second use, the purpose of which was to allow the student or the teacher to confirm the results of calculations of values measured in the laboratory. This second use will be reported later in Phase II as Experimental Analysis.

Just over half (28 of 50) of the teachers in the study had operated a computer program to simulate(model) a physical phenomena. A low level experience (median = 1) and medium level of feasibility (median = 2) of the respondents yielded ten teachers who provided their insights into this use of computers.

The use of a simulation program generally required a minimal level of computer literacy,

> If they know where the keys are-, the keyboard-, where the return key is. . . . Especially when they're going to put the number in and then wait until you tell them to press the return key. . . . For showing the demonstration or simulation, he doesn't have to know anything about the computer and programming and hardware and software or the disk beyond-, he has to know is how to put the disk in and turn the machine on and when the light comes on-. [#27:514]

although, for some teachers, problems with hardware/software compatibility necessitated more extensive measures.

Knowledge of programming was not necessary unless, infrequently, an assembly of programs on a disk was not accessed by the use of a menu.

> The only thing he should know is if it is menu-driven or controlled by the catalog. The catalog you have to type the "CATALOG" to get the program. . . . The only thing is, the teacher has to read the manual that comes with [the program.] . . . Some of the simulation programs . . . are machine language programs; they have got to go to BRUN. [#27:615]

The operating knowledge required for the use of the program by either a student or a teacher differed only when the teacher retrieved and used information coming from the management component of a sophisticated program.

> He would turn the student on it and then he would get a printout of the student-, all students' inputs and how each parameter worked out. And he could take that and sit down with the student and say, "All right, I noticed here that you allowed so many Big Horn-, so many dear to be killed and you allowed this much grazing and you got this result. Why was your next input this? Did you think it through or did you just want to try it out?" and "What happened here?" You can analyze it and what you're trying to teach the kid is a lot of analysis skills which is one of the higher mental levels - Interpretation, Synthesis, and Analysis skills - and that's what I really wrote the thing for. [#39:1080]

Hardware used for simulation included Apple II, Commodore 8032, and I.B.M. - P.C. microcomputers and monochromatic or color monitors. Characteristics of printers and other peripherals were not discussed, relative to this use.

Several features of the microcomputers and monitors were identified as significant for effective use of the simulation programs. To accomodate students with different learning styles, the simulation should present a variety of displays.

> When we teach kinematics to the students, we approach it algebraically, graphically, and pictorially, . . . so by entering those variables into the computer, you could see pictorially illustrated on the screen what was happening and you could ask the computer to give you a table of numbers representing what happened at specific time intervals which you could specify, like every tenth of a second, and you could also get it to plot a graph of that information. [#33:001]

The effective presentation of these displays was enhanced by several characteristics of the computer and monitor including the

- quality of graphics,
- facility for color,
- optional networking of computers to form an efficient, integrated unit, and

> 64k memory, single drive, PC machines, networked to a IBM-XT 10 meg hard disk. We would expand it to the full 640k and that would be networked in a lab and we'd license the programs across for the network rather than buy individual copies. . . . So what we end up with then is 20 mahines all tied together through a hard disk that can run - the upload and download time for the kids with proper software control can be almost negligible and all students can work off the same file and you're not running around with 20 disks and the IBM PCjr can tie into this network. [#08:779]

- a low-cost, dependable unit.

> The last few that we've bought have been Apple-compatible computers, just because of the price. . . . They have been very satisfactory; it is usually just a trade-off in terms of service and cost. [#17:666]

Maintenance of the computer for teachers commenting on this use of computers was minor with teachers meeting difficulties in a variety of ways ranging from

- teacher-tackled problems,

> I've worked on the Apple in the science department, like I said, drive speed and clean heads and if there is something mechanically wrong, like the door on the drive is busted or something, then I could probably fix that. I can pull a chip out as easily as the next guy, I guess. . . . But to diagnose, you know, if you don't have a diagnostic program to say, "Well, it is doing this. That is obviously this chip here", there is no way that I would know how to do that. [#18:5.10]

- to technical service provided under contract.

> I generally do very little maintenance because as soon as there is a problem - a chip is down, the disk is not aligned properly - we had instructions from our county that we shouldn't touch the machine; we have maintenance personnel . . . in the county central office. . . . That way, we get just `phone and he comes within a day-, that is for all of the schools. Everything. All. If he can't do it, he will take it in. [#27:401]

Information about simulation programs came from

- observing presentations at conferences, and
- reading printed materials.

> I don't look much farther than, say, magazines. The <u>Physics Teacher</u>, for instance, will always have a list of some of the software available and provide descriptions or, in a regular column in that magazine, there is a feature on courseware. I have looked through the [catalog of] MECC material that are available through the Department of Education. I haven't pursued it to the point of actually sitting down at the software. [#17:091]

The programs that were used by the teachers came from

- listings in printed references,

- colleagues,

> The only software I've looked through is this stuff that I've had on loan from friends. [#17:091]

- local commercial sales outlets,
- sofware banks of non-copyright materials, known as 'public domain', which are available from hardware dealers,

> When we got those 8032s, they came with a package of diskettes labelled "600 programs for your 8032." [#33:301]

- and national software vendors or developers.

> There was Whale, Rats, Population-, have now been converted to micro and they're available for Apple, TRS-80, and Commodore. . . . The micro versions run a little bit better. [#39:653]

Once the teachers knew about the programs that were available, their next decision was to buy or to build. Concerns that were present in their comments were for

- the personal time to procure the program,

> There's two basic costs; one is the teacher time cost. . . . I don't really think that I have the time to sift through the material that might be out there. It's sort of a hit-and-miss thing. You invest several hours, perhaps searching literature and you come away realizing that there isn't anything specifically what I want. So I find I would rather write the software specifically for my class. The drawback of that is that usually you do it in a hurry. It is not really polished; I'm not an excellent programmer by any means. [#17:1.5]

- the financial cost of the program,

> I would buy it-, I would recommend the school to buy it but the school is not going to buy it - they don't have money. [#27:195]

- the needs of the school course for the computer program,
- the degree of risk of purchasing an untried program,

> I have come to accept that there is a risk involved in

> buying software. This came as a package, these four diskettes. I don't know if I could have returned one that I didn't like and got a refund or a credit. I heard some of the results of the Math software that were evaluated by the Department of Ed. I gather that the risk is very high and I considered myself lucky that three out of four I liked. [#33:589]

- the need to explore the potential or limitations of the medium,

> We thought we would play with this and maybe get some reaction from my kids and just see what they were doing in this different learning kind of environment. [#13:17.2]

- and the decision to revise or to retire the program.

> I have started some simulations that I have just given up on them because I've realized that I have spent so many hours on it and I can't spend any more. I have one showing maybe wave pulses reflecting and just not satisfied with it. So those one, we scrap those. That might be similar to designing a test and throwing it away the next week when everybody bombs out and you realize that it was the test and not-. [#17:800]

The assessment of a simulation by the teacher was based on an extensive number of items falling, generally, into two areas, those items related to technical quality and to educational merit. The few items relating to technical quality included

- speed of operations,

> Now the original program that I have is written in interpretive BASIC and it's very slow so what I've done is taken it and I've compiled it so it runs in about an eighth of the time - it flies. You get the dots coming across and it runs to the printer. [#08:531]

- quality of graphics,

> Or if you're talking about a superabundance of deer, it would be nice to show a herd of deer, in color-, this kind of thing. That really is where the motivational

> aspect comes in and then you're truly going into interactive mode - tabular feedback is one thing, but literally a picture - you know how the cliche goes, so-. [#39:620]

- and cost of program.

> These were around $40 a piece these programs-, per disk, so price wasn't a factor except that if I were going to want to do this with many topics, those $40 would all add up quickly. [#33:235]

The teachers contributed many items by which they determine the educational merit of either a simulation program or simulation programs as a type of learning aid. Among those mentioned were

- graphical displays and simple programs,

> Then when they see the graphics of it, they get really interested. They are watching right away. They are curious to see which of the projectiles is going to go right at the nucleus and which is going to miss by so much. That type of interest then, on their part, I think creates a little bit more of a need to understand what is Rutherford's scattering. If it can increase the interest then it served a useful purpose. It has also augmented then what I've done in class. I certainly could never do the calculations because of the time factor, so the computer is doing the calculations for us and then graphing them for us. [#17:200]

- the degree of fit with the conventional or prescribed curriculum,

> The reason that I wouldn't have used it there has been to do with my approach to the inclined plane being more sophisticated than is exemplified in that simulation. It is a little too simple a simulation for what I need to teach the students about the inclined plane. . . . I don't think you would find many physics courses that would match up very well with that particular demonstration of the inclined plane because most of them, like I do, would want to emphasize the vector aspect. [#33:387]

- the underlying foundation of the simulation,

> Simulations are significant part of science. What became so clear to me almost immediately was-, that the students could quickly see was-, that the quality of the assumptions and conclusions that may come out of a simulation is almost directly dependent on the realism of the simulation and on the validity of the assumptions that are built into that simulation. [#46:908]

- the capacity of the program to foster higher mental activity,

> They had a little car travelling from point A to point B through a line across the screen. Then a question came up . . . something like, "How long did it take the car go to from A to B?" That was it. You had a number of choices. Essentially what you had to do was ask the information. . . . You had to have some idea of what was going on and then you had to ask the right questions which is the important thing. [#13:18.11]

- the ability to track the students progress,

> It's got to be individualized for the student and what you have to have then is some method of record-keeping that you get the student's inputs put into some type of file that the teacher can retrieve and analyze what the student had done and talk it over with the student; use it as an instructional tool like that. [#39:462]

and, lastly, the teacher must be aware of the purpose of the simulation; to portray a system

- with fidelity

> One is what I call simulation modelling and these are derived primarily from the pure sciences and engineering - that's modelling the 747s by hooking up the mainframe at Boeing or modelling a population curve in Biology or competing populations over a number of years. . . . The problem is that if you are using some real-, realistic formula, quite often the changes are so extremely subtle that the student at the High School level, with limited knowledge and limited number of process skills, can not tell you what is going on. [#39:434]

- or with simplicity.

> The [other] type of simulation is the one that I call an instructional simulation which does not necessarily try to model reality in its starkest, mathematical

> sense. . . . At the same time, we built in random factors, such as forest fires, drought, cold winter, and the kid could not keep all of those factors at the same time in his head and see what relationship they were because he didn't see the mathematical model so what you had to do was you had to fudge the results so the kid said, "Ah, hah; I've done this, I've done that and this is what the impact was" which would be greater than what the formula would give you and instead of being a factor of 5, it might be a factor of 50 or 100. Exactly, you would exaggerate to really point the kid to it. [#39:462]

This use of computers was initiated when the teachers received impressions of the disadvantages of other media and the advantages of the simulation programs for their science students. There was, for some,

- contact with other professionals,
- for others, limitations of printed and film media,

> I think [apparent motion is important] because it gives the student, I think, a little impression that this is really happening and here we're learning about something that is really happening. A picture doesn't convey that. A film loop probably could, yes, but the nice thing about a computer is it's so much more flexible than a film loop. You can't reach into the film loop and change any of the parameters. If you can change the charge-, if you can make the charges attractive instead of repulsive, you get interesting insights. In fact, you can show the students that all you have to do is change one sign on the program and you've suddenly got an orbit program. The gravitational force law and the scattering force law are mathematically equivalent. That usually really draws them in. [#17:263]

- the ability to incorporate typical experimental error into the data,

> What I did in order to make a transition, say with my Physics 10 kids, between theoretical kinds of problems which you run across in textbooks all of the time in which the data is always accurate and exact and everything else and the real world, even the real world of the air track, is to provide them with some simulated data. I have used the machines that way-, to

> crank out information which is not exact, a little scattered, that sort of thing. Give the kids a little bit of pratice first in working this data, drawing the graph and doing whatever they do, and then they will go in and do the real thing. [#13:10.6]

- or the difficulties frequently experienced with lab equipment.

> You can learn lots about the science process and about manipulating but without . . . something a little more concrete that definitely points them down the course and doesn't give them the idea that all experimentation is a randomized activity which may or may not work. [#18:7.1]

Using the simulation for science education requires a teacher to go through a recognizable sequence of steps.

> I must be informed of the hardware that is available, the software that is available, I must have funds or access to the equipment, I have to obtain it - either by going to a store or by mail order - I have to preview it, I have to decide where I want to use it in my teaching and for what specific purpose I want to use it and what I do not want to use it for. [#33:654]

A key decision involves planning

- where and how, in the sequence of learning activities, the students will use the simulation.

> I would use it not to introduce the subject but to provide examples for the class. . . . It comes after some teaching has taken place - several periods of it. . . . It would fit between the instruction and the home assignment of paper and pencil problems, so that it was providing the student with an example of what he was going to do when he did his paper and pencil problems. [#33:203]

- and who will control the operation of the program.

> Depends on how good the simulation is. If it is a difficult simulation to use, in terms of it asks you for a lot of information to run, I usually end up being the one. But whenever possible, I like to let the kids

> "play" with the computer because-, I guess one of my things is I like playthings in the classroom so, if they can handle the program, I like to build in a few minutes where the kids can sit around. [#17:343]

The difficulties experienced by the teachers who used simulations in their science programs mainly resulted from a lack of available computers which caused concern for

- management problems

> Usually I just have one computer in the classroom. That is the one drawback. So if you've got twenty kids trying to get at one computer, that doesn't work. What I sometimes do then is structure the class so that, while the kids who are spending ten minutes on the computer, the rest of the class is working on something else and we cycle them through it-. Usually two or three [in a group.] [#17:343]

- and a suitable learning environment.

> I did have the impression that the students were reacting to it in much the same way that they would have to a lab demonstration where they tend to be spectators rather than thinkers about what they are seeing. And I think that that would be a strong argument for more terminals so everybody actually gets a chance to participate and not just be a spectator. Then, had there been any questions stimulated, the student could have come to me or he could have got the computer-, could have got the program-, he could have tested out his question simply by running the program again with the variables that he had in question. [#33:3.9]

The teachers did not require specific assistance to implement this use but did comment on a broad system of support that was helpful for implementing simulations or alternate activities.

> My greatest source [of help] has been TORPET [users' group.] [#40:640]

> That particular experiment is something that is always thrown up as an example of something that is difficult to do and therefore we should do by simulation. I

> don't really accept that. I myself a few years ago was involved in some inservicing in which this was one of the things that we showed our physics teachers in the system - how do you operate this machine? The majority of them had never seen it before. From their point of view, I can understand that it would be a real problem. [#13:13.3]

Limitations of simulations on good teaching practices centred on four themes;

- the substitution of a computer program for an alternate activity,

> Another example would be some of the programs that simulate the motions of stars. What is preferable is to have the students and me get together in the evening, which we have done. It is hard; you don't always have kids that can be there and actually do some astronomy. Or go to the planetarium or look at some slides. [#17:700]

- the perception of reality of the simulation,

> We were then able to look at it and just say, "Alright, what are the value of predictions? What are the value of simulations?" And it depends entirely on the equation there that you are using to building the model. That was the objective that I wanted them to reach - that they are not going to leap to conclusions about certain data until they have had a chance to look at exactly where it is coming from. [#46:995]

- the effect on process skill development,

> I have some criteria for simulations; I don't like to simulate anything that I can do in the lab. For instance, I have seen simulations of titration. I know you can do some good teaching with them but I think it is important for a student to practice doing titrating, to swill a beaker around, to break the odd beaker, to actually handle the material of science. It teaches a lot of what scientific method is - the student realizes that there is a lot of technique, perhaps, involved in lab work. [#17:089]

- and attitudinal effects on the students and the teacher.

> Sometimes a simulation-, because it removes all the extraneous influences, it can almost seem like what you

> are doing is trivial. That is a real job. I think you just have to be aware of that `cause if that happens, you've lost completely the power of the simulation and you've, maybe, even done some damage. [#17:710]

The cumulation of the influences described above have an effect on the science teacher's role in the areas of

- preparation for teaching

> The person has got to understand the concept very well in order to simulate. It's got to be more than just a familiarity. . . . To make use of a simulation and to be able to answer the "Well, what if this is different?" type questions. But that is true of any good explanation in class. [#17:762]

- management of the activities,

> You've also got to understand, in terms of time in the classroom, how much time it is going to take to get anything out of the simulation. [#17:793]

- and the academic climate in the classroom.

> As a teacher, I feel good when students start [suggesting revisions to the simulation] because it shows me that they feel they have a stake in this class and that they are involved in it. So the computer, I think, is a way of building a little bit more activity into the course. [#17:298]

Tutorial The level and kind of knowledge required was well within the ability of the user of the tutorial, whether

- for the teacher using the SuperPilot program

> The language is already in very simply. The simple basic computer literacy-, once you have got that-, once you have got the early, early fundamental protocol of using SuperPilot - which is a matter of about a twenty minute look at the tutorial - you could write yourself a very easy, linear, properly reinforcing program for whatever grade level you wanted to choose, easily in the space of an hour. [#37:525]

- or for the student using SuperPilot,

> I haven't seen anybody that can't handle, once they have been through the early, early fundamental literacy - and we are talking kindergarten and grade one and two and everybody else - once they have had experience-, and we have used it sort of a set pattern with introducing fundamental computer operation to kids-, once they have handled that, they have no trouble with the SuperPilot. We've set the choices that they make and how they respond and the style of interaction to suit their needs. So far, we have only gone down to four with SuperPilot in-, grade four in terms of science. [#37:714]

and, for the programs available through a terminal from a mainframe, for

- the teacher who began the sequence,

> I found a computer and put it on a coupler. You called up your code - we had a code that we had to use to get our particular section of the mainframe put into it. All of the schools had a storage place. When that was coded in, the menu came up with the different programs that we had in there at the time. . . . And then I would just start the program. [#43:257]

- or the student who followed through.

> From then on, it was very friendly. It just asked you to do things and you did them. It wasn't too hard. [#43:5.9]

The kind of knowledge needed to write the tutorial program was of two types; programming skills and instructional design. The extent of programming skill required depended on

- the perceived need of the teacher to be familiar with the operation of a program where the BASIC language is exposed,

> I think you need to know some BASIC so that you can understand how the program is working-, what's happening, even if you're using a purchased program. I think it is to any teacher's advantage to have a little

> knowledge of BASIC. You don't need much - I had five two-hour sessions is all I've ever taken plus-. You don't have to take a University course, I'm quite convinced of that. So that you can adapt the program to your needs. [#43:714]

- and the characteristics of the authoring language that was being used or on the requirements of the tutorial.

> To utilize [a tutorial program] fully, you have to have some programming knowledge . . . because what you have to do is, if you don't want the student, for example, when missing the question to be put back to the previous page - maybe you want him to be put back to three pages ago - then you have to go in and have to be able to make changes in that program. You can also include graphics so, instead of putting a text on a page, you just leave it blank and then, later on, you go into the program and, at that point, you tell the computer to draw some graphics on the screen. So you have to be more than somewhat knowledgeable about the programming. There are some fairly complicated things there so it's certinly not for the novice user. It would be for someone who is heavily into computer use. [#28:247]

the need for knowledge of instructional design was present for all applications and included

- a background in programmed learning

> I didn't have too much trouble setting that up with my experience with the UNIPACS in the first place. That is another pertinent thing, I think, for anybody who is going to write this material. Before they start writing for a computer, they should get good at writing tutorials in general-, which I had that previous experience. The only change I had to make was in how to put this into BASIC language for the computer to understand, that is all. [#43:656]

- application of learning theory to the program,

> You really should invest some time in either instructional design, and come up with a mold or a model that works and then apply it, or start to get creative-, and either one. It depends on the teacher's resources and energy and context, but it is valuable in the tutorial thing. The ones that really work are the ones that you do well from a design point of view. [#37:532]

- and to the requirements of the student population.

> [The students] want changes. For example, the fours. They'll want more reinforcement and they'll want shorter blocks - they will want many more sub-units in there. Fives and sixes tend to want to persist longer - they don't need the bells and whistles as much - so [the teachers] will want some control over that. They want control over sound-, character styles and sets aren't as important to fives and sixes as they are to fours - that type of input and/or control. [#37:732]

Differences between the knowledge required by the teachers and the students were present where

- security requirements were evident

> They don't give permission for kids to use the phone or even know the phone number or the code. The kids weren't allowed to know those things. I believe that was school board rules. I'd have to phone it all up and hook it up for them. [#43:5.8]

- and the tutorial had a management component.

> The only real added sophistication was perhaps a manager and a score program that the teacher would be segregated from the student on and that is all. [#37:744]

The hardware that was used for the tutorials varied from a LA-36 teletype terminal to a mainframe, an IBM-PC, a Commodore 8032, to the most common Apple II microcomputer.

Although the computer was frequently selected because of provincial support for courseware, there were features about the peripherals that caused the teachers to prefer specific requirements such as

- the number of machines,

> I think if I had thirty students, only about a third of them at any one time would be going onto-, be working on something like that else. They would have, first of all, other things that I would have assigned - they would have to accomplish those too. The time would be

> a factor. Others have only a very limited interest in the computer for their method of learning; they might prefer to use some other mode. [#43:17.3]

- input devices,

- a moveable trolley to facilitate resource sharing,

> We'll be able to unplug that one, roll it down and we will share that with kindergarten. [#37:762]

- the selection of a specific type of monitor,

> We've got an NEC monitor, a small one, lately, in the last year, that resolution-wise, is really excellent and color-wise is excellent as well. We traditionally have been getting Amdec and Panasonic but I'd say this new one has got some good things about it. The Apple III green screen we've got-, I wouldn't say there is much real difference there, if it is adjusted properly. Yes, we've been that route [using black and white television.] Not great. You get so much bleeding and such poor general characteristics that it is not realistically of value to us to go that route. There is times it's almost essential when you are dealing with a large group of kids so you make that trade-off regrettably. As far as graphics goes, though, it is not good. [#37:271]

- and, for teachers using a main frame, the decision to use a teletype terminal or a video screen.

> One of the problems there was simply the volume of paper you went through. That was one of the problems. Every response, input and output, was always on that. . . . Other than that, there wasn't any major problem. One of the nice things about it was that the students could keep the hard copy and that happened very often. Because it was hardcopy, students would simply take the pile of paper and they could, on their own, read through all the instructions so it was a set of notes that they effectively got which was one of the positive features of it. That's right, it's all there plus the questions that they had tried so they had ten or twelve questions that they could always, perhaps, just go back in terms of reviewing. [#44:999]

The teachers had minimal involvement in servicing the equipment because of maintenance contracts

> We are all under contract so I don't have to fool with

> maintenance at all which is nice. I just wouldn't have the time and I really don't have the inclination or interest. . . . We have very low incidence of maintenance problems. The ones we have had, generally, have been solved in the matter of an hour or an hour and a half. The computer goes over, gets diagnosed, comes back fixed. Easy. It has only been a matter of chips and the odd keyboard problem, but that is it, nothing else. We don't even bother with diagnostic cards or anything else. They would be easy to get and easy to do but we just don't feel that we have the need. We have identified the budget. We would rather spend out time elsewhere. [#37:750]

but, when operating from a mainframe, occasionally experienced loss of the program.

> The only problem that was more severe than that was the mainframe would be down when you wanted to use it to printout. They would be down at inconvenient times all of the time-, sometimes without warning, sometimes with warning. Oh, you would be working away and they would interrupt with a little message on the screen that the mainframe would be down between 2 and 5 today and this was at 1 o'clock. [#43:345]

Demonstrations of the courseware or authoring programs were the chief means of introducing the teachers to possible programs.

> There is always the Clearing House - they oversee the listing and they evaluate it. Number two is my own colleagues in different schools who have used it. Third is conferences and the vendors having some more kinds of programs for displaying. Then I have a chance to use it and see how does the program work and whether it is meeting my needs, the student's needs, and the current curriculum and my expectations-, what I expect to get. Very satisfactory. That is my biggest source-, or exchanging material. [#27:762]

The authoring systems were purchased from local suppliers and the completed tutorial program came from a variety of software firms advertising in brochures. One difficulty experienced by teachers who are shopping through brochures is that of receiving for evaluation the program.

> I get a lot of catalogue material in that is relevant to teaching and course materials with the computer. In the past, we have applied for and written away and received some preview material. . . . There is a guarantee that if you don't want the program, you send it back and your money is refunded-, but there is such a hassle as you are aware in the educational system-, as I am sure there are in other places-, with presenting that money first and then getting it returned and all the bookkeeping and accounting procedures you have to go through so that is becoming a real problem in terms of getting access to some of these programs. [#42:2.8]

The teachers who had developed their own tutorial programs were generous with criteria that they consider when developing a program. Highest on the list were

- their personal limitations of available time and patience,

> First of all, I would have to consider whether I had the time to even consider doing it. . . . That would be the number one resource that I would have to look at - time to write this program. [#43:12.6]

- the directing of the program to achieve acceptable objectives,

> My objectives are the second parameter I have to look at-, is what are my objectives for the lesson or unit? I look at my objectives and then try to write something that would accomplish those objectives. . . . You can get the content objectives from the commercial programs but the process objectives have to be hand-made. . . . I don't see me using commercial-built programs or tutorials very much, ever. I think you have to design something that is suitable for your personal biases and objectives. The only one way to do that properly is to write it yourself. . . . I would think the ultimate best program would be written by the teacher who was trying to use it. [#43:12.7]

- the potential to create and formatively evaluate a program,

> I think time to see how the kids react is important - what types of things the kids would say. "This would be useful if you would stop it here and display this. This would be useful." I think that is necessary. [#18:12.1]

- the usefulness of the completed tutorial program,

> Another thing that would govern that is going to be how much we are going to use it. Are we going to use it within the school? If we are, with four physics teachers, is it going to be worthwhile? If I am going to be the only one that is going to use it for one day out of the year, is it that worthwhile? [#18:12.4]

- the recognition of personal styles of teaching and learning,

> We try to look at different approaches, because we believe that all students do not learn in the same manner-, and this we don't have built up in every unit but it is again something that we are working to. This is where the Super Pilot, I think, will come in and is why we purchased it. [#45:6.5]

- and the balance between the logic and the logistics of branching in tutorials.

> I have tried to write with branching but that, I found very difficult - it's just a matter of how big the tree becomes. How far do you keep branching? And the problem is then to try and eventually come back to where you want to go, otherwise, this thing just becomes colossal. So I found the easiest was, you ask a question, the student responds. If it's not correct, tell him it's not right and try again. And usually I terminate after two responses - if it's incorrect, I will then come back and say, "This is what the answer is. Let's try another one." and go to another question-. . . . I can see the logics of branching but I just find that it's very, very difficult thing to work with. [#44:1101]

Virtually every teacher had developed criteria by which tutorial programs were evaluated. The first decision by teachers was whether to use self-authored programs or to use commercially-developed programs. Features that affected this decision included the capability of directly controlling various characteristics of the program that the students would use.

> [Super Pilot's] real strengths are that, being an authoring language, it gives us the freedom to design our own, very simply, and with relatively minimal requirements up front in terms of knowing a sophisticated language and programming skills. Its advantages are numerous in that regard. That is one of the reasons why we have elected to go that way. [#37:024]

If a decision had been made to use prepared programs, the necessity for evaluation was apparent

> I would suggest to the teacher who was going to use it for the first time, that they preview it before they use it. Guard yourself and know what the program allows. What the material is. If the material is concurrent with the curriculum. If the difficulty level in the questions is to a standard-, up to your expectations. . . . I would tell all the teachers to watch out because sometimes the program may not turn out the way you want it. You must be very careful, preview it and find out if the program is linearly arranged, if it is menu-driven, how many questions there are, does it maintain the management systems there, . . . if the student has control over the developing and manipulations, or whether you control the management system, whether you can read out the answers. [#27:820]

and produced a list of criteria used to evaluate these programs that was extensive and included

- the appeal of the program to the students and the quality of the performance of the program when used,

> I find that the kids are too awed with the games idea - if you don't have something graphic and you have a lot of pages of text, and it is not in color and stuff like that-, you know, one of the bare, very obvious type facts of programming-. It has got to be flash, bam, whiz, bang or else the kids don't want to sit in front

of a machine and press-. [#18:2.0]

- the facility for both student and teacher control over the program,

> It would ask them, "Do you want to do this part or do you want to skip it?" . . . Then it started right off, "Do you want to do the whole thing or do you want to just look ahead on the aerobic respiration?" If they wanted to do everything, they would start off in the anaerobic respiration. If they decided they wanted to leave at any time, they had an option to leave and go to aerobic respiration or go to the end at any time. So they had options. If it was too easy, they would skip parts. They could do it two or three times but go to a different part each time. [#43:155]

- and the usefulness or capacity of the program to meet a variety of learning situations.

> We have applied for and written away and received some preview materials. We have looked at some of those things - most of which we find is not directly applicable either to the curriculum the way we present it in Alberta or doesn't again match our particular style in teaching. [#42:2.8]

The introduction to tutorial programs frequently began with teachers ordering preview materials from software houses.

After the exposure to this use of computers, the actual entry by the teacher and the class had three stages;

- the screening of the program,
- the resolution of the "wait or go" dilemma of a buyer,

> So we felt, rather than constantly search and acquire and search and acquire, and wait for the evaluative process to run its course in the science area, it was easier for us to meet our specific focussed needs at the time to author very short Super Pilot programs. . . . We came across Apple Pilot, realized that there was another newer and more sophisticated version coming

> available and waited seven months to finally get it. [#37:024]

- the familiarization of the teacher with the operation of the program,

> I basically worked through the tutorial and then worked through the manuals, developed some lessons that were basically canned, went back, re-evaluated them, had them evaluated through our evaluation process to learn some things there. Investing about a month and a half in that process . . . during the school year. . . . It is a very focussed thing. There will be times at school when I'll have intense times but most of the time, it is on my own after school. [#37:137]

- and the integration of the tutorial with the normal class program.

> When students used the computer under me, it was always as a review - you had taken the stuff already, whether it was a drill in chemistry or a tutorial in biology. [#43:098]

Fewer difficulties were experienced by teachers who used an authoring program than by those who used a programming language, such as BASIC. The teachers had to

- determine the extent of branching to be provided for the students

> [Super Pilot] has that capability; it is a matter of whether or not we have got the strength and energy to get all of that in there that thoroughly. Generally, we will limit ourselves to one or two remedial branches on a particular segment of a lesson. [#37:485]

- and cope with the achievement of quality graphics using an authoring language.

> [If I had time,] I would create some tutorials in it on some aspects of science to begin with because that's my area - it could be Math although Math would be more difficult, using IBIS, because really to present Math successfully on a screen, you pretty well need to go into a graphics mode rather than a print mode to draw

> things properly-, you have to exit the program, create your own graphics and then you tell the program, instead of looking for a text page, to go and get the graphics you created so it's actually a separate part from the program. [#28:279]

The support system in place for the benefit of the teachers was of both an formal and an informal nature. On a most formal basis,

- an academic class provided guidelines,

> I think the class gave us the general format - that you must have input, you must make it interesting and vary your approaches, and stuff like that. I think that was good. That was good bread-and-butter stuff. As far as the actual mechanism as to what to do when this didn't work, that was harder because the lab assistant was spread too thinly. [#18:14.10]

- as did groups of teachers formed to evaluate software,

> He is our main biology man, and he had access to some of the materials that they have sent him from the Department of Ed-, . . . so he had looked at some of the materials that they've presented and so he knows what to look for and how evaluation-, and so he has had a look at some of the programs for me and with me, and this was one that he felt that he probably could put to use in class. He tried it with a couple of students and liked what he was seeing and what he was getting from it and so he decided, "Well, we'll buy this one, it is reasonably priced." and he felt he could make use of it. [#42:3.11]

although other informal associations were

- created by the individual teachers,

> We are starting to basically form a group of people at different centres that we know we can get ahold of and all have certain levels of expertise. It has been a valuable thing. [#37:154]

- or formed through contacts in the school system.

> The chemistry fellow took a great interest in computers while they were here and started doing some tutorials and then we got the people from the school board to come out and give an inservice on BASIC program and we

> did [redacted] guess, about five nights of inservice. [#4

In addition to the above sources of general support, additional specific assistance for clearly identified problems was received from a variety of sources including

- commercial software suppliers

> I've only really had one that didn't provide me any kind of overt satisfaction in the process of evaluating their instrument-, only [software supplier] company that just wasn't terribly willing and interested. Most of them have been more than willing to help. [#37:154]

- and manuals designed to aid other users.

> He made up a program so that the Phys Ed. teachers could come and use it without asking him all of the time. He had a booklet-, just a few sheets of paper and instructions on how to log in. [#43:276]

Only two limitations on good science teaching were noted by the teachers. Uncertainty was expressed about the capacity of a tutorial to respond to

- various learning situations

> I don't think the computer is a teacher substitute in any case whatsoever. I think you can respond to the students much better than the computer can. No matter how many branching routines you have, if the kid spells the word wrong, the computer won't take it. If he mispronounces it, you'll understand. . . . I think the face-to-face, to me, is the best way. [#18:13.11]

- various learning styles,

> Some kids tend to be book-type kids. Other kids want that context on the computer and do better because of it. . . . Not all of them are totally positive with it. Some of them tend to find it imposing a little bit. Some of them aren't-, are not intimidated by it but some of them don't find it fits their style. The more visual kid definitely grows with it much better than a child who is a silent reader at his own pace. A high speed reader tends to be frustrated a little bit by it.

> A child who reads very well and at a very high rate and comprehends tends to find, often, the page turning a nuisance and too slow so they do complain. It is done on a frame scrolling basis and the kid-. It is done in high res now, done with a graphics speed that is pretty significantly reasonable, I find, but the kids perceive it as too slow or too monotonous. [#37:388]

- and the decreased personal contact between the teacher and the student.

> The price that is being lost to us teachers is being able to be in contact with the child when they are [using the program.] We don't have that opportunity very often. I'm sure the lessons could develop better if we had a better opportunity to do that-, both as an author and as a teacher, to see the effectiveness of them. That's one weakness. It does remove the child at times and it doesn't allow us to interject, at times, our personality into it. Some teachers would definitely want more of a personality into that instruction than the computer situation allows them. [#37:412]

The major roles present for the teacher using a computer, apart from that of teacher-as-student learning a new skill as a user of tutorials, were related to the diversification of activities within the classroom.

> I give time for them to work on their labs and do tutorial materials and so on and I go from group to group and talk to them and help them. . . . I just found that whenever there is a whole lot of options, some kids choose one, some kids choose another. They rotate themselves over a period of time. [#43:656]

These activities required the teacher to

- prescribe or approve appropriate student activities,

> That is the time when, given those circumstances, the child can say, "I have a half-hour block that I need for the computers. It is acceptable for me to go and use them?" "Yes." . . . The kids are pretty-, the 4, 5, and 6s, now that they are literate, are quite aware and quite demanding of their time and they want it so they will seek it - they seek it actively. They have a

> roster schedule and they either have their assigned time which is definitive assigned lab time or they have a quantity of flexible time that goes up for grabs. [#37:327]

- and accommodate other teachers or their students.

> Since then, we have become more flexible and we have structured their situation now so that, if there is another release time during the week, they will either utilize the computer in their classroom or they will come into my classroom and utilize one of the two that is in there for their half-hour blocks during the day. [#37:310]

The diversified learning environment and its resultant movement of students and other activities within the school,

> Being in an open area, you are used to noise all the time. . . . In this school, . . . we still have the open area and we are all-, there're four classes going on at once here sometimes; teaching there, here, the lab going on over here, all at the same time in this one room. . . . There is some teachers that can't handle that; they are gone in no time. Others, it is no problem. And I've been here eight years, it doesn't bother me any. It took a while to get used to. [#43:302]

was, for a teacher who is accustomed to working in this atmosphere, not a matter of concern.

> I don't think that there has been much change in my role. I am still being a facilitator, and that is my basic role. [#43:656]

The teachers who had developed or used tutorials voiced concerns about issues that had not been included in the schedule of questions. These other dimensions of using tutorials were

- the desirability of cooperative development of tutorials,

> Sooner or later, it would be a healthy thing, I think, to get an authoring language in a situation where lessons are being developed by either a cooperative small group or by a group of individuals that have both the technical end of things understood, in terms of instructional design, but also having the content knowledge. [#37:485]

- the importance of a critical evaluation of the effectiveness of tutorials,

> If you are going to use tutorials, you have to first say, "What concrete evidence am I going to have that this is a good method?" [#18:16.11]

> And how do we gauge the return from the child's point of view also? How effective really is it? Until we get some better data or some harder data on it-, it's effectiveness and get to relatively objectively compare-. [#37:444]

- and the clarification of the level of risk to health of the students.

> The back of my mind is always saying, "You've spent three hours in front of the set. Is it [safe?]" . . . I don't think technology is addressing the radiation problem of computers as much as they should. [#18:28.2]

Drill and Practice Maintenance of basic skills was one of the four most common uses for computers by the questionnaire respondents with a moderate level of both experience (median = 1) and potential for future use (median = 2.) During the interviews, nine teachers described, in varying degrees of detail, their experiences with this form of computer assisted instruction.

Whether the exercises were drill, where there was no rule to guide the students to the answer, or practice, where a well-defined rule was followed, the programs used by the interviewed science teachers required only plug-in and turn-on operation. In addition to isolated and unfortunate mishaps encountered while unplugging peripherals from the computer while the power was on for both units, other technical knowledge was required, and not described in the manuals, when changing programs in the CBM 8032 or changing the case of characters to be printed.

Students, in one instance, using a pattern created by a teacher for use by other science teachers at a school, had created a drill and practice program as an end-of-course activity. No differences between teacher and students were thus seen in the programming knowledge of using BASIC to write a drill and practice program. Although the program was of educational value to the student-authors, no judgement was given of the educational merit for subsequent users of this student-prouced program.

The school computer used for drill and practice were Apple II, PET, and CBM 8032.

Concerns that surfaced that have implications for purchasing computers included

- the need for the computer to be selected on the basis of machine-specific software that is suitable and available,
- the benefits of having a single extensive system throughout the school for portability of programs,

- the requirement of access by academic classes to the school's computers, and
- the support by a repair facility, whether a local dealer or district sponsored, with a stake in minimizing down-time and service costs.

Maintenance, including cleaning printers and repairing disk drives, had been provided both by a technically-willing and manual-guided teacher and the dealer who had originally supplied the computers.

Reading periodicals and promotional literature appeared to be the main method for achieving teacher knowledge about available programs. The reviews of currently available software in a variety of periodicals, including TORPET, Creative Computing, Compute, etc., needed, however, to be read with reservations about the thoroughness of the report.

> Current reviews, I think, although I am not too sure how much they tell me because you don't know anything about the reviewer and his or her biases in this whole learning thing. [#13:9.6]

Other sources of information about computer programs included

- flyers sent by supply houses,
- reviews about, and personal inspection of, software recommended by the provincial ClearingHouse, and
- browsing amongst the displays, including PLATO, at conferences.

The source of the actual programs previewed or used came from

- exchanges with friends or associates,
- public domain banks of programs supplied by dealers or by users' groups,
- commercial supply houses, e.g., Merlan Scientific, and,
- rarely, as loans from local software dealers.

The factor which dominated any consideration of development, revision, or implementation of a drill and practice program was the time that could be given by the teacher with a second factor being the provision of an aide to function as a human "file server" for one program used at sixteen computers.

The interviewed teachers, learning from their use of programs from a variety of sources, indicated that they would prefer using programs that included

- branching to difficulty levels of questions or concepts dependent on the student's achievement in the program,
- an option for the teacher to revise the wording of the questions and answers,
- teacher control over the subsections to be selected in the review from the major concept covered by the program, and
- reinforcement routines that reward performance rather than offer incentives for students who select incorrect answers.

> It was quite interesting except-. Here we were; there were four or five educators, some of the administrators as well, involved in this demonstration and everyone's initial reaction was, "I wonder what happens when those guys-, those things, get you when they come down?" So the immediate reaction to this was to make errors to

> see what would happen. I found that totally distressing. So we looked at it and then we went away. It was lovely color and everything else, but the whole objective of the exercise seemed to me in reverse. [#13:8.3]

The interviewed teachers began considering using their computers for drill and practice because

- there were many models commonly available as public domain "freeware" and
- for motivation of students and variety in the lesson.

> One of the things that I've always felt is that the more varied you can make your lesson, the better. This was a way of varying it, adding a motivator. And drill is one of the more boring things you can do in life, so that is where I started from. [#13:387]

The varied ways that the teachers began using the computer for drill and practice included

concerns about the program and computer that would be used for the exercises, including

- learning BASIC so that programs could be built for the content that the teacher had selected for review,
- designing a framework into which local questions and answers could be embedded,
- building a bank of subject-specific questions and answers, including using final or unit exam questions and one of the multiple choice alternatives in a true/false format, and
- gathering the equipment and programs together at appropriate times and places to enable the students to

review

and concerns for the students and the learning routines, such as

- estimating the amount of time that should be spent in this mode of learning,
- identifying those students who are in need of this review activity, and
- selecting the sequence of basic skills for the students to follow while reviewing.

Difficulties that were encountered in computerizing the drill and practice exercises were in the form of

- inadequacies of the software that were not detected in the descriptive literature,
- a computer, television, and trolley that were purchased and were then used only occasionally, and
- students who would break out of the program and change the code or go directly to the data array where the answers were stored (resolved by loading and immediately removing the disk from the drive or by converting the questions from BASIC to SuperPILOT in which an author disk is needed for assess to the program code.)

The teachers who used drill and practice received help from

- other teachers in their school system,
- competent students in the teacher's classes,
- programming manuals or courses offered by school jurisdictions, and

- users' manuals for the computer languages.

The specific assistance that the teachers received was in the nature of programming the computer.

The only limitation identified for students who were using a computerized form of drill and practice was the propensity for increasing the consumption of class time by this low-level skill building activity.

No new role was identified by the interviewed teachers except for

- making the computer and/or programs available for extra practice outside class time or
- allowing students to copy the program so that review could be done at the student's home computer.

Instructional Gaming The competition in a gaming program that results in 'winners' and 'losers' was a use of computers that few teachers in the study had experienced (median = 0) and that had only a low (median = 1) perceived level of feasibility. Only three of the teachers who were interviewed described the knowledge needed by a science teacher to effectively use gaming in their classes.

The interviewed teachers stated that minimal operating skills should be required by teachers and students to operate any educational game beyond the fundamental skills of

- inserting the program disk or cassette,
- closing the disk drive or cassette door, and
- turning on the power switch for computer.

No knowledge of programming was deemed required by games users.

The computers used for gaming by the teachers were Apple IIs with disk drive and a cassette-loaded Radio Shack Color Computer.

The characteristics of the computer that were identified as enhancing gaming in a classroom included

- fast performance of the central processing unit, a characteristic of the central processing, electronic circuitry design, and programming language,
- an attractive graphics presentation,
- a stable company for after-sales service and sofware support, and
- for a programmer, a dialect of BASIC, e.g., Microsoft, that minimizes difficulties translating programs from other computers.

The only maintenance that was described was the replacement of a keyboard under warranty or the application by the teacher of alcohol and tuner lubricant to sticky keyboard keys.

The common availability of games in the community of computer users enables the teachers learning about games from friends and associates in casual users' groups and professional specialists councils.

The programs that the teachers used came from commercial software companies, contacts made through users' groups, school district licensed distribution of software, e.g., M.E.C.C., public domain 'freeware' or were written by the teacher-user.

The two factors that restricted the introduction of educational games by the interviewed teachers were

- the lack of funds for purchase and
- the restricted availability of time for classroom, inservice, and learning time.

The factor that was the chief reason for the teachers introducing variation, including educational gaming, into the classroom activities was the increased attention that was given by the students and the enhanced recall of the activity during the later discussions.

> I sense there's that concentration, interaction and, Glom!, you got 'em kind of thing. . . . Once you've got them at that point, to expand, I think, is quite easy because, then you can always say later on in your lesson, as you go back and review, you could say, "Well, remember in that Odell Lake?" and, for some reason, they always say, "Yea, I remember." Whereas before, you could have had it drawn on the board and you say, "That diagram." "Well, which diagram? Oh, yea, that one." Forget it, but just the new situation-. [#05:976]

These users of educational games had compiled a lengthy list of criteria by which they evaluated gaming programs for possible inclusion into their classroom. These criteria could be considered to be classified according to one of two main emphases;

a) technical features, such as the
   - operation without users issuing disk system or programming commands,
   - provision of a HELP option or menu,
   - user control over the duration of involvement in the contest, and

b) pedagogical features, such as
   - complex tasks requiring high level mental processes including the integration of skills or information, e.g., Lunar Lander,
   - tasks where opportunity for "development of power" was present and, through self-improvement, the student could reach higher status levels, e.g., moving from entry level #6 to mastery level #1 in SpeedMath, or
   - events where each contest is different from previous ones resulting in variety and a sense of exploration of the limits of the game's environment.

The exploration of the program by the student was seen as the reason for students purposely selecting incorrect answers to observe the resulting mayhem, a controversial aspect of gaming that elicited many negative comments. The interviewed teacher noted that if this form of negative reinforcement is provided by the designer/programmer, instead of giving no reinforcement for incorrect responses, the novelty is usually exhausted and soon ceases to be an interesting choice for the student.

Two features that are frequently present in computer games and attract much interest but were not advocated by the teachers for classroom use because of lack of apparent educational merit were those that could be classified as

- destructive thrillers of the arcade variety, e.g., Moon Rover, and
- role-playing fantasies, i.e., Dungeons and Dragons.

The teachers, in the introduction of a game into their classes, had gone through two identified patterns of use, i.e., using the game

- on a merit basis, e.g., as a reward for students who complete assignments, and
- later, as an activity integrated with other classroom activities and in which all students would have a turn.

The new role of the gaming gave all students, whether fast or slow, achievers or strugglers, an opportunity to experience the learning possibilities present in the game and allowed the teacher an opportunity to present the computer program as an engaging source of information, e.g., using Odell Lake to identify food chains amongst fish, rather than as a source of entertainment.

Difficulties were experienced by both the students and teachers during the game-playing in the form of

- for students, using Odell Lake graphics to predict predators solely on the basis of the depicted size of the fish,

- for teachers, the accommodation of the motion and noise of students moving to and from the computers, and
- for both, the problems of
  - access of a class of students to a limited number of computers and
  - need for assistance in note-taking during information retrieval from the program

(solved by pairing of students at the computer.)

The interviewed teachers sought assistance in writing, programming, and swapping educational games from members of users' groups and high school students and Computing Science teachers. Periodicals used by the interviewed teachers included Computing Teacher, Creative Computing, Nibble, and Byte.

The possibility of games in the classroom limiting effective teaching was noted by the interviewed teachers who recognized the temptation to students to want to stay with the gaming, thus introducing extra management or control decisions for the teacher.

For the teachers who were interviewed, no changes were identified in their roles as teacher, except for minor ones dealing with

- establishing a fair rotation of students to the computers,
- identifying the most suitable means of using the computer game, i.e.,

  - as a carrot for completing assignments,
  - as a source of information for exemplifying lesson content, or
  - for guided discovery of a science concept, e.g., using a worksheet to record data for later analysis and recognition of patterns,
- and handling increased social interaction between students as participants in the gaming situation.

Other factors that the interviewed teachers identified as influencing the probability of games entering into their classroom activities included

- the freedom of the student to compete with classmates on an equal basis in games in which none of the students had prior background knowledge, e.g., Odell Lake for students with minimal actual fishing experience,
- a background of the teacher in educational psychology to aid recognition of the forces present in the gaming interactions, and
- a perception by the teacher that the games port on the computer could be perceived as another port into the computer for the students' learning activities.

> If you can devise your topic into a game that they're playing, I think the child will learn a lot better and a lot faster and this is where the challenge comes in - is how can you take a subject matter and present it in a challenging way that becomes a game? I think that boils down to simply, "What is teaching?" [#44:895]

Electronic Chalkboard The use by the teachers of the computer as an "electronic chalkboard" or "overhead" was limited; only three teachers contributed their insights to what a teacher would need to know for this use. Within the broad definition of the electronic chalkboard as "the device used by the teacher in the class", were a) a page-turning program for giving notes, b) programs for calculating values for refraction of light in water and for the terminal velocity in air, and c) a laserdisc presentation.

The knowledge of the operation of the computer was determined by the nature of equipment used. For the simplest situation where a program is menu-driven and a single monitor is used, the normal booting and responding to menu prompts were required. If multiple monitors and/or a laserdisc is used, then plugging interconnecting cables into appropriate fittings and adjusting the devices for optimum display becomes an added necessity.

Knowledge of programming to display, or to control the display of, material becomes a requirement only if the teacher has the interest or if the purchased material requires modification to make it suitable for the teacher's class.

For the most part, there was no difference between the level or kind of knowledge of a teacher-user or a student-user; many students used the material as independent learners outside of class time. The only extra task required of the teacher was the survey of the contents of the laserdisc prior to class to identify, and enter into the program, the location of specific frames and sequences for later use in the lesson.

The hardware and peripherals used as electronic chalkboards included an Apple IIe and normal size TV screen, a TI-99 wired behind the tuner of an Electrohome Educator TV, and a Magnavox LaserDisc Player controlled by an Apple II and using a 26 inch monitor for the display.

Purchase of the equipment required

a) an understanding of the need for quality of display necessary for the size of the intended audience and the nature of the text, graph, or diagram displayed,

b) knowledge that a manual controller and any computer with a games port are alternate means of controlling the display of a laserdisc,

c) an appreciation of the quality of the picture and the time required to access specific content of a laserdisc, and

d) an awareness of the benefits of alternate methods of controlling a computer's operation including light pens, touch-sensitive screens, and the mouse.

Because of the recent introduction of these teachers to this use of computers, no knowledge was available concerning maintenance skills necessary for a teacher-user.

The sources of information about specific programs or laserdiscs was not identified by the teachers in the study. The periodical Physics Teacher was the source of a listing of a program to display the terminal velocity of a freely falling object, MECC supplied a program on simple harmonic motion, and WICAT Institute and Simon Fraser were the sources of laserdiscs on biology and general science content.

The ever-present restriction, time, was cited as the most critical factor in determining the teachers' development of, or familiarization with, a computer program for use in the delivery of a lesson.

The decision by the teacher to use an electronic chalkboard, in general, or a specific program was based on several criteria, including

a) the extent of the appeal of the material to motivate the student, the prerequisite for all learning activity.

> The kids are sort of attracted to the computer. . . . If you bring something in and it is going to be computer demonstrated, it has some . . . appeal just because of that fact. When you are teaching, you want to capitalize on anything you can to get the interest up. [#18:4.3]

b) the ability of the computer to solve difficult mathematical problems quickly, e.g., terminal velocity of falling object,

c) the display, where applicable, of the concept in graphical form,

d) the design of the program to achieve closure of a concept, and

e) the opportunity to practice good communication skills significant to the concept being studied, e.g. sign of vectors.

It was in the area of implementation of the computer for this use that the teachers most freely described what they had learned. The demonstrations of the laserdisc at conferences by a staff member of the province's Computer Technology Branch and the in-class lectures by University staff were frequently cited as creating an awareness of the possibilities of this medium.

Entry of the teacher to this use began with examination, and revision as necessary, of programs or screening of the laserdisc to identify and record the location of segments of the disc relevant to the proposed lesson.

Difficulties encountered in implementing this use included

a) lack of access to equipment because of competing school programs or priorities resolved by the purchase of necessary equipment by the teachers' personal funds,

b) readjustment of the pacing of the lesson because of the lower writing load on the teacher resolved by handing out written notes to students and making the program available to students outside class time,

c) slow loading from a low cost cassette tape resolved by loading the tape during the break between classes, and

d) revising the program to permit values for parameters beyond those allowed in the original program, and

e) resistance by the teacher's peers to the use of the laserdisc has not been resolved.

These teachers, in this innovative use of the computer, generally received help from outside their school, usually from other teachers or staff from the province's Computer Technology Branch.

Several limitations were identified by the participants:

a) the "canned" lesson, whether on a page-turning program or on a linear laserdisc sequence, is very difficult to modify in response to the spontaneous development of the concept in the lesson, in comparision to an overhead projection or chalkboard erase and redraw,

> You have got your class all planned out, you go in there, the kids ask one question, and you get off on some terrifically good side idea that is related and that you are going to cover eventually, but, "Boom. This is the time and the place." I don't see that on an electronic chalkboard. [#18:23.7]

b) the effortless presentation of notes should not displace the experimental work normally part of the development of the concept,

c) the rapid calculation of values of variables may overwhelm the student who may not appreciate the arduous achievement of the original development of the generalizations in the concept.

The comments made by the teachers did not identify any roles of the teacher significantly different than the usual ones of a) identifier of suitable resources, b) manager of learning activities for the whole class and c) responsive adjustments to the needs of individual students.

Two dimensions of "good" science teaching using this media were raised by the teachers:

a) the possibly narrow perception of the limitations of the computer, in this application, to the presentation of text, diagrams, and graphics, and
b) the concern that the class may be conducted to fit the program available, rather than the tailoring of the program to meet the needs of the students.

Laboratory Instrumentation There were no teachers in the study who had experience in this use of computers. There were, however, several who anticipated this use and had therefore developed some considered perspectives and it is on these that the findings are based.

Concern about knowledge of the operation of the computer and its ancillary devices included the primary task of interfacing the components of the laboratory instrumentation system and the ports that would be used to achieve this interconnection.

Although competence with programming was not anticipated, there was an expectation that a background in statistics would be necessary for a competent interpretation of the data.

A student who used a computer for this application would need only to respond to menu prompts; a teacher would also have to be aware of the limitations of the program, the manuals, and the devices and the computer.

The teachers had reviewed catalogs from Cambridge Development Laboratory and had ordered a kit from Holt, Reinhart, and Winston that would read and display measurements of physical phenomena.

Because several teachers were at the stage of considering this use, several factors were uppermost in the minds of the teachers. Firstly, the physical property that would, in view of the practical curriculum applications, most likely be employed would need to be anticipated. Then the devices would be selected to achieve this application and, considering limited school resources, purchase of the necessary components, e.g., time interval clocks, temperature, voltage sensors, etc., be prioritized. Teachers would also need to know what capability the computer had for receiving the signal from the device; whether serial, parallel, or game ports were available or whether an analog-to-digital converter was required. The teachers who intended purchasing equipment for this application would also need to consider the trade-off between the amount of time needed to become orientated to the equipment and its operation and the extent of the resultant expansion of curriculum activities.

No information was available concerning maintenance skills except the checking of the physical hookup of components in the case of failure of the system.

Sources of information about specific programs or devices were mainly catalogs from commercial supply houses.

The only teacher who had done any development of electronic circuits to monitor signals from external devices had developed a pragmatic position about the time required for development.

> The [experiments involving instrumentation] that would be most practical and the ones that are done most frequently are the dynamic questions where you measure time intervals as a function of distance - that would be something that would be used quite a bit. . . . If they would get that far and do that, then that would be quite an advancement, I mean, an up-grading of what they are able to do. . . . I, and everybody else, has hardly any time, other than do the basic job and it's like you're on a fast track all the time. [#30:185]

The program should allow teachers to either display the values of the physical parameters (raw data) or to proceed to various interpretations of the data, e.g. graphs.

Sources of information about this use were experiences in laboratory facilities at the local University and flyers from commercial supply houses.

Difficulties that had been experienced by the teachers were primarily the high cost of the devices and programs and the perceived limited application of the material and an uncertainty about the balance between the exotic and functional character of the concept.

The only support system that had been developed was with a laboratory technician at the physics lab at the local University.

A primary concern about this use of computers was that the level of sophistication should not overwhelm the student.

> I believe experiments are only good as far as the kids understand what they're doing. [#30:352]

A additional role for the teacher, prior to using the computer for laboratory instrumentation is to verify the fidelity of the devices and program as measuring what is claimed and then to label the material as worthy or worthless. This caution is because of the remoteness of the produced results from the measuring process and also the limited trial-by-use of the equipment by the teacher's peers.

The likelihood of the teacher using the computer for this use was dependent on the stage of the student in their process skill development.

> It depends on the situation. . . . This is one of the labs that we do. Let's set up a glider and, instead of talking about uniform motion, let's hang a mass over the end so we get some acceleration. I want the kids to do some initial work themselves to see what kind of thing comes out of it. Now, after they've done that, they understand that, under these circumstances, this glider accelerates, then I wouldn't have any problem [using the computer.] Let's say, for example, moving on to a Newton's Law kind of experiment where we change the mass . . . to use, say, something like that to then speed up the analysis - they know that is going to happen but what happens when change the variables? - We can do that very quickly. I think that . . . I would do it in that framework but my objective is different then. [#13:12.2]

Experimental Analysis Students of four of the teachers had used a computer to check the results and calculations of labs. The students used either programs that calculated values parallel to those performed manually by the student or that printed a graph and slope similar to graphs previously drawn by the students.

The operation of the program by the students required a minimal orientation.

> It takes about half an hour letting them fly with it, at the beginning of the year, to learn how to operate [the VISICALC program.] . . . They teach themselves. You remember in Computer Science, when you had something-, it just wouldn't fly-, it just wouldn't work, and you leaned over to the next guy and said, "Hey, how do I do this?" [#08:505]

The only knowledge of programming required for this use of a computer is, when a program is initially set up to do a graphics dump to the printer, the teacher/programmer must determine, and embed in the program, the required command to activate the machine language routine or the printer interface card for the printer.

> [The control code is hidden] just inside the program. . . . It is just a character string that you send out to the printer. . . . "Control IG" is usually the graphics dump command. [#17:391]

The student only needed to respond to questions on the screen.

> I give the students an option; "Do you want a hardcopy?" and on the basis of his reply, it will either turn on the graphics dump or not. Most of the time they say, "Yes" and away it goes. [#17:391]

The hardware that is needed for this use is a computer, a printer, and, for graphics diplay, a printer card.

The features of the hardware system that was most reinforced was

- the capacity of the machine for easy access

> I wheel the machine right down from the Computer Room and bring it in the room. I want my own machine in the room but they won't give me $5k [#08:461]

- and a graphics card for printing high resolution displays.

> In the last couple of years, the graphics-capable cards have sort of replaced the older ones. It is just another newer feature that is selling so almost any card that you buy today, if you have a graphics-capable printer, will most likely come with a graphics card. [#17:444]

No maintenance was described as necessary by the teachers for this use of computers.

The teachers learned about aspects of the programs that they considered important by

- digging for information

> So I started asking around and, at that time, the only way I could get the Centronics to do it was to go through a graphics dump program. [#17:420]

- and noting progress of colleagues.

Specific programs that were used by the students for lab analysis included a spreadsheet, public domain, teacher-authored, and copyright programs.

> So I got a copy of the graphics dump program from WestWorld. . . . It was part of the library - they just gave it to me. [#17:444]

The teachers in the study had, in the main, not developed the programs that have been described but one commented on revising and the usefulness of a program.

> I see [revising] as far more likely than starting from scratch and writing a program to do this. [#18:20.7]

> I see . . . the busy work taken out of the lab as a far more useful thing than tutorial. [#18:20.9]

Features of programs that were recognized as desirable by the teachers included

- the variety of applications,

> I've used that primarily in association with reaction kinetics lab that I've done but it's mostly surrounding the Spectronic 20. There are a wide variety of things one can do - the reaction kinetics, the equilibrium constant, and the ksp solubility is what I use it for. [#08:401]

- the correctness of the product of the analysis,
- the quality of the screen display,
- and the increased amount of information given to students.

The possibility of using the computer to aid the students in the analysis of their labs occurred when the teachers observed students working under conditions that were not desireable; most notable,

- the time spent on repetitive calculations or graphing.

> The other thing that I do use the computer for is for Experiment 29, an equilibrium-. . . . I find, with the kids, the calculations take too long and I find it is better for them to put their data into the computer and get their print-out, rather than spending time on calculations. That is one definite use that I have in Chem 30. [#35:]

- and the difficulty of marking labs based on questionable calculations.

> Now, when I first did this kind of thing, I said, "Well, how am I going to know whether or not they have made errors in their calculations?", because I want to get rid of errors in the calculations so they can spend their time on the conclusion - we can't make a very good conclusion if they start off by saying, "If my calculations were correct, then . . . ." or "I don't think my calculations were correct, but, ..." So you have got all these kinds of answers. [#34:18.9]

The provision of the lab analysis program for the use of the students did not relieve them of the responsibility of doing the analysis themselves. The teachers usually required one complete sample calculation/graph to be shown before the program could be used for parallel work.

> The bottom line is, "To get that piece of paper with your data crunched on it, you must present to me one set of calculations completely done, completely correct, the proper sig. figs., and all." They'll whine and they'll complain and they do. "You've got to buy your printout with a correct calculation." . . . They've proven to me, once, they can do it - then I give them all the rest. [#08:424]

> I'll introduce it maybe a month into the course when the kids have done maybe four or five lab activities

> and have prepared graphs. They understand what goes into making the graph. I don't want them to be illiterate in terms of "They've had the computer do all this for them." . . . So they'll be quite proficient at making graphs and it is strictly seeing the computer as a tool that they are going to use. [#17:362]

The teachers provided an orientation to the lab analysis program by various means, including handing out copies of the screen presentations.

> I then typed out all of the displays so they could come in and they would have their things all written down as it would be on the display. [#34:28]

One of the teachers had made an initial attempt to solve the problem of calculating lab data by earlier providing a calculator for the use of his students.

The normal scenario of the classroom/lab when the lab analysis program is in use is one of multiple activities.

> Some of the kids are banging their pucks together on an air table and the other kids are in the corner checking their data - that is two focal points in the room - the rest are working on stuff. That is still a big improvement. . . . Two air tables and two computers in your classes is totally using their time efficiently. [#18:22.10]

In the quest for a method to assist their students analyzing lab data, difficulties that were met and overcome included inefficient graphics printing procedures.

The teachers received specific assistance when implementing this use by

- reading manuals
- and receiving assistance with programming difficulties.

> Some of the kids have helped me with some of my programming - like one kid was trying to help me relocate memory there. . . . So some of the kids were helping that way as far as programming-, some of the

> teachers helped. [#18:23.3]

The teachers did not identify any limitations for good science teaching associated with this use of a computer.

The major impact on the role of the teacher whose students use a program to assist with lab analysis were the different way in which labs were marked.

> What happens, when I'm marking the lab, I don't have to check their calculations. All I do is read their conclusion and mark it. . . . The time used to going through their data and making sure the numbers work, I now spend reading their conclusions. [#08:424]

Another teacher used a program as a replacement for a calculator for checking the students' calculations.

Phase III: The Testing and Evaluation

The post teaching/learning phase was the area in which virtually all (49 out of 50) teachers had some experience or prospects of using a computer, mostly for test production and test records.

The process of evaluation, with all its associated activities, is the third phase of a sequence which begins with setting goals and gathering materials, followed by providing learning opportunities (usually through class activities), and lastly evaluating the process.

> First of all, we have a published set of goals and I set my goals as to what I wish to teach. . . . The goals are there and they are specific behavioural goal statements. The teacher attempts to teach to the goals, accomplish the goals, and then to evaluate the

> goals. . . . If . . . I can get some data back on how my students did in these specific areas, I can modify my teaching based on that. . . . And one must always be going back to the primary worth: What I am trying to accomplish - the goals - and, in my mind, I think nothing could improve the state of education better than that. [#40:918]

Test Production The process of evaluating the progress of students usually includes the production of tests. This use of computers ranked high amongst respondents on both the experience (median = 2) and the feasibility (median = 3) scales. Of the three quarters of all respondents who had indicated a potential for contributing in this area, eleven teachers made comments during subsequent interviews.

The results of the pilot study, indicating that there are two approaches to test construction, from test items or from whole tests, was confirmed in the main study with eight of the interviewees working with tests constructed each time from individual items and two teachers storing and retrieving whole tests.

Two teachers used test item retrieval programs that required a minimal knowledge of BASIC programming only when the data was initially entered. In these programs, the text for the test item was stored either as data statements in the BASIC program or as entries in the fields of a data-based system.

> I purchased EasyFiler which is a commercially available DBS program and then set the data base up using rather strange field sizes so I have two lines, for example for the question. I have 78 characters I am allowed to put my response in, A, B, C, and D. I then have a slot for the correct response. I have a slot for a selection . . . so there is this Yes/No selector thing. And it works extremely well. I have all my multiple choice items . . . That's how I got them in. . . . And this is what I'm doing for the multiple choice items and . . . I have 500 items in Chem 10, 20, and 30 combined. [#08:001]

The use of these test item generators to print questions only required that the teacher follow directions presented by the host program.

> The way that you use this program, you look at the syntax of the questions and you pick which ones you want and the order you want. Then you use the program and you put the number of the question in that you want. Then you just print them out. It prints them out in the proper numerical order, just the way that you put them into the program. [#35:2.0]

A program with somewhat similar features is the Test Generator by MECC that

> Allows you to enter up to 200 questions and you are able to enter them by objective number, say if you wanted to do inferring, for example, you could call it objective number 1, and . . . So you enter all your questions. . . . It will ask you how many questions you want, by objective, and it will randomly choose from within that bank and print those questions on a paper. It's a shell program so it will accept any kind of questions you want to put into it. [#28:141]

In one large urban district, teachers and students, using a teletype terminal or a microcomputer and modem, had access to a bank of test items stored on a district's mainframe computer. These test questions were available to teachers as random or specific questions of a designated content objective or to a student at school within a framework prescribed by the teacher.

> So I see for next year, I would say that I want a test on this unit and testing these objectives; I want some knowledge questions, I want some comprehension questions, I want some open-search questions, and sort of design a course in that. Then, as the students progress through the unit, they would go to the computer and they would get a test that is unique for them within the framework that I have set so that, when they have written a test and another kid comes and says, "What did you get on the test?", there may be a chance that the same question would turn up again but not necessarily. [#41:3.5]

Lastly, under the general heading of test item storage, are questions, generated using a template, that differ only in specified criteria, such as compound, mass, volume, etc., and are produced without manual control of the values of these criteria.

> What I have is a program I've written, using concentration calculations, for example, where the code will say, "NNN grams of XXX compound are dissolved in NNN volume; calculate the molar concentration." and those are one type of question that will appear in this thing. An alternate one is I give the number of moles; an alternate one is I leave the volume blank; an alternate one I leave the molar mass blank. The compound is always randomly generated. . . . It also runs through and calculates all the answers and I can run off a hundred different-, and they will be different; some of the compounds will come out the same. [#08:029]

The second technique for test production uses a word processing program to build and store whole tests.

> The data bank is actually a test bank; it isn't a test item bank, it is a test bank. Because of the type of programs that we have, which are simply word processing programs, SuperText and Gutenburg, . . . we have put in tests, quizzes, exercises of various kinds, worksheets,

> that are complete in themselves. So you would print them out as complete items to hand out to the students. [#34:1.5]

Students did not have access to any of the test production programs except for the printing, previously described, of unit tests from the main frame.

The teachers in the study used a variety of microcomputers including Apple, Commodore, IBM PC, Radio Shack, a teletype terminal by Lanpar Technologies, and Centronics and Epson printers. Each of these devices had their own operating characteristics; no features were described as essential for the use described here except for a concern for compatibility between these devices affecting the transferring of files, printing, or other educational uses.

> I use the school's printer. . . . Everything's totally compatible except for subscript/superscripting - the school's printer won't do it; it was bought before Graftrax option was available on Epson, . . . You have to do it by half-rolls and I've done it but it's a programming pain-in-the-butt and I just ignore it. . . . It's all in one straight line . . . there's no ups and there's no downs and that's strictly a function of the printer that we have at the school. I don't have a printer at home - I haul the school's back and forth at the moment. [#08:194]

Problem-solving skills were needed to tackle specific maintenance tasks; the teacher had to know how to identify the component that had malfunctioned and thus

- the appropriate organization responsible,

> When the modulator went, or the modem went, it was sort

> of a matter of trying to sort out whether it seemed to be a problem from the SAIT [mainframe test bank] end or our end. . . . I didn't want to have LanPar come in if there was nothing wrong, so in that case, they probably would have charged me a service charge. I wanted to make sure that it was most likely something wrong with the hardware we have got here. [#24:837]

- the appropriate action to take,

> We did have a solenoid problem as well with the drive-pins at one point and had to replace the complete head . . . and even the strap that leads to the head . . . I did a lot of fixing of fuses and so on and we bought fuses and I would take the thing home and I would solder in the fuses as well in terms of getting that kind of thing done. But we tried to send it out on occasions and then we would have to borrow another Centronics from the Math department or something in order to keep our production going, particularly at exam time, when you look at exams that are being produced for all of our ten different courses that we offer, you are looking at final exams for all of those twice a year, and . . . all of the unit exams and chapter exams and quizzes and so on. [#34:1.10]

- or a knowledgeable sales organization.

> I just know that, with our experience at home and even here, to hook up to the TV, you have to go out and buy a modulator. . . . We always phone Micromedics for information and they will tell you anything that is for PET and Commodore. . . . We didn't like the Commodore printer; we got an MX80, I think it is called. . . . but we had to buy it a special link first of all to connect it . . . so that adds another $65, but you need that linking. . . . There is all these little things here. . . . Anybody that has no idea of what they are doing or doesn't have access-, you go to buy these things and the salesmen don't know anything; they are only interested in selling. . . . I have contact with [Micromedics] because we bought our school equipment there. This is how I got to know them because I was taking things in for repair. [#35:14.1]

Information about the software used for test production came from diligent searches in periodicals and of vendors, frequently supplemented by published references and personal contact with active models.

> There was a comparative magazine article as well that compared Magic Window with Super Text and a whole bunch of other things and I went through all the features there. . . . I think that was provided by the store, by West World. . . . I was able to get ahold of the program there from a guy in the city who had been using it to produce some textbooks himself. Then I used it at home for a period of time, or a few days, and then gave it back to him and ordered it. [#34:4.2]

The teachers chose to implement their particular mode of test production because of specific net benefits that they perceived to come from that use. The teacher who used an automated test generator using a template hoped to achieve individual student effort combined with instant feedback and less teacher prep-time.

> The beauty of it is I can have different worksheets for everyone in the class but they're identical; it's just the numbers and compounds have changed and you honestly get individual work. . . . As far as I'm concerned, it was designed primarily as a time saver and what it does allow me is to give more questions with correct answers available right away, as opposed to: I make up the worksheet, then I sit down and spend the time working out all the correct answers as opposed to this thing does it for me immediately. [#08:078]

The teachers, ambivalent about using the MECC Test Generator, described the weaknesses of the program.

> No diagrammatic material and it will not handle [super]scripts and subscripts because it's a simple print statement. . . . It doesn't have a word processing capability. [#28:161]

Pulling quality questions from a test item bank on a mainframe using a computer and modem at home was anticipated by one teacher,

> I am waiting for the test banks of Biology to come on by and, as soon as it does, the majority, probably, of

> my tests will be what I do at home. . . . In some cases, I'll pull my existing tests because it is tried, tested, and true, but I am certainly interested in what new material and resources are out there, so I will certainly be calling off questions from that computer when those are available. [#31:271]

- and the extensive resources of the bank facilitated pulling parallel or individualized tests.

> We are talking about being able to just draw out a test from the bank. . . . That will be the first thing that will be available-, is draw out a test and if you like that particular one-, or you select your test for level of difficulty and set it up in parallel tests. . . . I see eventually . . . being able to tell the computer the level of difficulty and the objectives to be tested and having each individual student go and get their own individual test from the computer, writing it, and putting the answers back in and having the computer basically mark their answers and give me the grade when I ask for it. [#41:+28.1]

Word processing programs had many advantages over other methods of producing tests,

> First of all, I wanted a word processing program because I am not the world's greatest typist. . . . I feel that I want to present the students with a quality that is decent; hand-written looks hand-written. Getting the secretaries to type for you is not an easy job; you have to do it a couple of days ahead but, sometimes, the night before you need to do it. . . . Plus, things can change in your lesson; you can suddenly think of another objective after the test was made that you would like to change. [#43:849]

- and over other specific word processing programs.

> One of the other things that came out in terms of science was accessibility to other fonts, for example, Greek, which we use in some cases fairly considerably if you are getting into the nuclear chemistry. . . . With Gutenberg, you have access to these Greek fonts in two ways; . . . You could draw it yourself on the screen . . . [or] you could use what is called a User Font which is available through the Gutenberg word processing, that you can call up and it will download into the printer, or you could even call up the

> printer's capability of using that kind of thing which you couldn't do within the Super Text program. [#34:5.2]

For the entry of the teacher into producing tests using a computer and a specific program, an early requirement was

- the exposure to the program type on a demonstration disk

> [The Test Generator] originally came as one of the Demo disks that we got from MECC when we first got our computers. We didn't have any programs and we've heard about the Minnesota Education Computer Consortium and one of the disks they had at that time was the Teacher Utilities. [#28:185]

- and the pilotting of the system in a similar setting.

> The . . . teachers all went over to take a look at it in operation. They showed us how it worked and what you can get from it. We also spent an afternoon at Forest Lawn High School and observed what it could do from a more sophisticated standpoint. [#24:890]

During the use of these programs for test production, a number of problems, some of which have been referred to previously, were experienced by the teachers. Additional problems met by these teachers included

- the inadequacy of operating manuals,

> The manual was terrible. . . . The manuals are not written by educators at all. . . . I found that, for both word processing systems, that I have produced a one page summary of their whole manual for both Super Text and for Gutenberg so that people can get in there and learn how to use the thing. But you do need this kind of step-by-step kind of procedure. [#34:11.9]

- the organization of files of tests,

> So we left the old ones with the unorganized fashion as our backup and we took all of the Unit A stuff from Chem 10 and we put it onto Unit A diskette . . . and that is the way we operate now. [#34:10.4]

- arranging for security of shared text files, and

> Now you have some difficulties in there in the sense that when you are using the word processing system, there is a possibility of destroying what you have got on there - this is where you really need your back-up. There are some people who have a knack of destroying things on computer diskettes; with twelve teachers within the department, you are going to find at least one person who generally has difficulty. [#34:11.1]

- innovative arrangements for handling diagrams.

> The only drawback is diagrams so what you do on the question is you put in "Diagram ET1." - that means Energy Test 1. Then I have to keep a book with all of the diagrams in it - no cut and paste - just one page with the four or five diagrams and that is all you really have to run off and give to the kids and say, "This is your diagram for that test." . . . I have one sheet with all the diagrams; whichever diagram I need for that question, I give them. Then I don't have to cut and paste every time I have a test and check it over and make sure it works. [#09:943]

The ease of implementation of producing tests using a computer was affected, at the beginning of the use, by

- persons or agencies with whom the teacher had contact,

> We were discussing the Q-MATH computer tie-in with the-, through the school system-, with the public board, and so I thought, "Why not try it at home?" . . . I came home that night and loaded it in and just tried getting random questions off it. Sure enough, I got fifteen question off so I saved it on disk, plus I ran it into-, through the printer. [#31:]

- manuals or training aids provided by the supplier,

> The manual . . . came with six tapes-, actually three tapes, two sides each. We played the tapes and followed the manual and learned how to use it. [#43:23.1]

- and, on a continuing basis, by various individuals.

> We also have got a teacher transferred to our school from St. Francis, and he knew totally how to operate the machine so, really, our inservicing, to a large extent, with the specifics has come from him. [#24:971]

There were no limitations to good science teaching identified by the teachers. A factor, not perceived as a limitation by the user, was the presumed solubility of compounds in questions generated using a template.

> That's not a concern of mine at all because what I'm attempting to do right then in Chem 10 or Chem 20-, solubility considerations don't really come in until equilibrium when I do it in Chem 30 and it's actually not in the Alberta Curriculum. The alternative is to drop the sulfide ion and you've solved half the battle there. [#08:159]

Most of the teacher identified ways in which this use of computers had an impact on their role as teacher. Common themes were

- the amount of time needed,

> One of the biggest problem that I feel-, I can see, it is too much work. When we got this computer here, everybody had good intentions. But it is a lot of work on your own. . . . I am doing it for my use because I feel it has saved me work-, it will save me a lot of work. [#35:11.1]

- the necessity of being able to type,

> If you are going to do word processing and you are going to be able to do it with any sort of capability at all and do it consistently over the years, you are going to have to be able to type. . . . So the training of teachers would have to, I would think, include typing skills as a kind of a prerequisite. [#34:14.2]

- having a computer at home,

> So I will certainly be calling off questions from that computer when those are available and doing it at home because-, just to do it at school-, I'd rather do it in my own environment. I know how to control my system here, whereas the terminal we have at school-, it's in the library, everybody is walking by. [#31:271]

- determining the level of developing programs - for self or for others,

> You would have to polish it a lot and that's part of it as well; I wrote it for myself - it does exactly what I designed it do do. . . . I know what I'd do if I was to market the thing. There's a lot of things I would add. [#08:127]

- the excitement of working with new materials,

> It has me champing at the bit. I see all kinds of uses and things that I want to do. [#28:204]

- and facilitating the revision of test materials.

> It saves me an awful lot of time now because most of my tests are in there and in the bank and I can go in there and I can look over the comments that I had from the kids in the classroom . . . Everytime a kid says something about a test question now, I make sure that I make a note of it on the test and . . . I go back in and I change that question-, the wording on that question. The quality of my questiobs is very high compared to what it used to be. . . . That is were the major advantage is over a typewriter in terms of the quality of the material. But it does cost you time. [#34:9.9]

Test Scoring The extent to which the teachers in the study used an automated test scoring/marking device is indicated by the low (median = 0) level of use by the respondents to the questionnaire. A novel test-scoring procedure incorporating marking, reporting, and recording was created by a school administrator in a neighboring school system who used a mark-sense card reader and a microcomputer.

> He uses a card reader. His students write a test and the cards are these long strip cards so, for the multiple choice, they're simply pencilling in this typical score. He then just has the reader and a monitor at the door and his disk drive set up and as the students file by, they put their card in the slot. They keep walking and about four steps down from the card reader is the monitor that gives them their

> immediate results and those results go to his mark management program right away. So for the sake of that one step that the student takes, the student has instant feedback and the record keeping is taken care of.

The contributors of information for this use of computers were three teachers, one each in an Elementary, a Junior High, and a Senior High School. Two of these schools used a card-reader made by Chatsworth; the other device was produced by Scan-Tron. The Chatsworth reader required connection to an Apple microcomputer; the Scan-Tron was a stand-alone in the scoring and marking mode. Both machines used special mark-sensing answer sheets/cards. No respondents were asked about system-wide test scoring using a main-frame; information about this facility emerged during interviews relating to item/test analysis.

The apparatus had been demonstrated by suppliers or by system personnel. Significant aspects of the performance included

- reliability of performance,

> Somebody in the public board demonstrated it to me and I thought, "Forget it; I can see nothing but problems with that machine." . . . He couldn't get the thing to read properly and the thing was only a year old. . . . "For a thousand dollars, it's not worth ten" because the thing wasn't reliable and you're also tying up a computer and you can't tie up a computer for the amount of time people want to mark and use it in a classroom. [#30:670]

- availability of service facilities,

> We were looking for a local service contract; "Well, we don't have one." But we do have an agreement . . . they sent us up a bunch of parts for the things that do tend to wear out and they also promised us that, if the thing broke down, they would ship one up right away

> while we shipped ours back down. [#30:740]

- and the extent of the local network of users.

> I contacted our purchasing people to see if anybody else had acquired one. . . . They said, "Yes, there's a few other people that had it." I called the supplier. Yea, they were aware of some people in the school system that have it. . . . We are aware of, I think, five or six other schools that have it, Junior High more than Elementary, I gather. [#37:1015]

The maintenance of these devices resulted from the mechanical aspects of their operation and varied from routinely checking and adjusting the sensitivity control to finding repair facilities for major overhaul.

At the lowest level of knowledge, a teacher or a technician needs to be able to monitor and adjust the sensitivity of the optical reader. The Chatsworth reader seemed especially sensitive to varying shades of pencil marks and card thickness. Users had initiated a periodic, ten minute, test routine using a check program and a set of test cards to determine the need for adjustment.

> It is a simple adjustment of a simple potentiometer. . . . Test it first and then do it. . . . This is the second time this school year. [#37:942]

To avoid problems caused by pencils of differing darkness and cards of varying thickness which apparently caused problems with the card reader, this school has standardized its pencils and answer cards for the computer-scored tests.

> Now we've uniformed the pencils; we have a particular batch of cards that we bought in bulk so they're all identical now and that works considerably better. [#37:935]

At a higher level of problem-solving skill, some competence in diagnostic techniques may be required. Because the mark reader is sensitive to light pencil strokes, one teacher had erased stray marks leaving the rubbings on the card.

> You pull out your eraser and erase and, I think, that's where a lot of the residue came in. . . . You're cleaning up the cards with the eraser right there. [#05:130]

After this cleanup, the teacher then observed that

> the machine wasn't operating very well . . . no pattern developed, so I tore the machine apart and finally figured out that there is a drive wheel there that gets very dirty and it puts on marks on the card. Like it will pick up in one area and put in another area. [#05:060]

Analysis and solution of this problem included reference to the operator's manual and treatment with 90% isopropyl alcohol.

Difficulties with false readings with the Scan-Tron or with an earlier, similar machine were not mentioned by the teacher.

At the highest level of maintenance requirements, a machine that has given lengthy service may require finding a repair facility for a major overhaul.

> We had an optical marker in this school for about five years. . . . Everybody used it, it was such a popular item . . . So what happened is that it started wearing out and it had to be repaired - it wouldn't mark the first two questions right and so on. . . . They couldn't find anybody in the city to repair it. [#30:665]

Extensive down-time for repairs to the machine may introduce concerns for continuity of the school operation and conservation of resources.

> You need a marking machine here all the time - we weren't ready to send it down there and wait six months. . . . We found out there were better machines on the market that did more. . . . You see, they take different answer sheets, the new and the old machine, and we still have a lot of old answer sheets around so we'll fix it up and then use both until we run out of the old answer sheets; for what it costs to get it fixed, we can't afford to throw it out with all the extra answer sheets around. [#30:800]

The operation of the Chatsworth reader involved fundamental skills of booting the program disk and responding to a menu of options. Students at one Elementary School, in the interests of computer literacy, routinely put the scoring program disk in the drive, close the door, turn the power on to the computer, monitor, and reader, and

> run the score program and then simply follow the screen directions in terms of . . . entering the number of students, number of questions, input the keyed answer card, input the student number one card . . . and away you go. So they can handle that readily; it is not a problem. [#30:981]

The time required to process a class set of answers varied by a factor of three, depending on the machine used.

> I would think that twenty minutes as being about what it would take, twenty minutes to thirty minutes. . . . It's deceiving because, like, if the [Chatsworth] machine is operating and there doesn't have to be any adjustments. [#05:300]
>
> It would take me twenty minutes to mark that exam, whereas with this [Scan-Tron] machine-. I gave two exams today; the last ten minutes, I went down, I marked them, I put them all together, and I brought them back within ten minutes. [#30:830]

The Scan-Tron card reader, being completely independent, was simple to operate involving insertion of the answer key sheet, the student's answer sheets, and a report sheet onto which the device prints elementary test statistics. The device also prints the correct answer for each question in the margin of the student's answer sheet.

Early editions of the scoring program used by the Chatsworth card reader had a programming error resulting in the program (which had been acquired from unknown sources)

> going into loops. We would get . . . locked into a loop. The person would end up stuck inputting the same card. . . . I figured that one out, too. I changed this one. . . . The loop problem is right in here. . . . When the printer was on, it didn't work; if the printer was off, it worked fine. [#37:+015]

This problem was not incurred in later versions of the program.

The Scan-Tron card reader/scorer, used without the optional interface to a computer for statistical analysis, does not require a computer for test marking and, thus, no difficulties were experienced with malfunction of the computer program. The computer program for the Chatsworth card reader was available in a number of forms from various sources.

> We got wind of a new version by letter, contacted the supplier . . . About a month later, arrived a brand new disk with this all done on it. . . . At no cost, just straight from California, here you are. Real nice support-, just super. [#37:925]

One teacher had a software program that had been modified to signal the results of reading cards which apparently had double or no responses. Also, the results for the class were printed in a format which both increased the volume of paper needed for statistics and lengthened the time required for marking a set of answer cards. This teacher had already invested time to solve a problem generated by false readings produced by a dirty drive wheel. Hence, the major concern for this teacher was the balance between the time required to correct the problem and the time saved if the problem was corrected.

> So I would see, if I were really gung ho on programming, a person would be delving in that area but the payoff there is so terrible for the time you put in. [#05:325]

The teachers who used the Chatsworth reader considered beneficial

- a program that speeded up the marking process,

> With the bigger machines, when they have a batch, they run the whole batch and then they look back and say, "O.K., there's problems here and here." It's faster to do that rather than to break the batch as it goes through the scanner so I am just assuming that if it's possible for the bigger machine to do that, then why wouldn't it be feasible for this one to run the whole batch? [#05:430]

- had improved analytical and diagnostic capabilities,

> Now it does a little bit better analysis, but it also gives us the capability of adjusting the optical reader ourselves, rather than having to rely on a service person or a service agent to change-, to make up for differences in cards. [#37:930]

- and discriminated between ambiguous responses by the card reader.

> The one weakness in the card reader program, . . . it should pick up either 'no marks for that question,' or it should pick up and signal, in some way, that it 'didn't read that question properly.' [#37:1130]

The teachers became aware of these machines by reading journals, by viewing the machines at conferences, or by exposure at the school.

> I read a review of it which was positive all the way down the line. It was in . . . an Education Administration Newsletter . . . put out in Minnesota. Sure enough, here it was, talking about using it in their school systems for instructional management scheduling and all kinds of things, and also test marking. So it was really, really positive. [#37:1025]

Following awareness of the potential of the card reader for test scoring, the teachers surveyed the suppliers and brochures issued by manufacturers, determined the extent of local users of similar devices, and proceeded to purchase.

> Our V.P. said, "Well, I've run across this new machine. Do you want to come and take a look at the brochure?" And I looked at it and said, "It looks good." . . . We talked to the supplier and we looked at the brochure. . . . we looked at it and we liked it so we bought it. [#30:695]

All teachers using both card readers had problems with students marking their answer sheet without having stray marks or inadequately erased old answers, both of which led to incorrect scoring.

> There is a training element to building the student's familiarity with it so that it doesn't affect the score. In other words, the marking of the card, and marking it carefully, is not of sufficient distraction to the student that it would impinge on their concentration on the test. I think that's a learning curve of relatively short duration but, nevertheless, it is not a familiar experience with a lot of the kids, yet. [#37:1102]

The mark sense cards for both card readers allowed for only numeric identifiers; the cards had no provision for the student's name. The teachers responded to this limitation by ordering the cards according to the class list. This procedure also gave an additional benefit of faster entry of the test results into a marks record program.

The teachers received assistance from a variety of sources including the operator's manual, students, teachers, and administrative personnel in the local school systems and the regional specialist council. The assistance included trouble-shooting programming errors, advice concerning maintenance procedures, and doing the leg work for finding a replacement card reader.

Objectively scored test items marked by the card reader included multiple choice test items and, depending on the reading head and the specific machine to which it was fitted, true-false and matching questions and survey polls.

The effect on the student and the teacher of the use of the card reader was seen by the teachers as mainly favorable.

For the students, the main benefit was the immediacy and the discrimination of the feedback. All teachers returned the marked cards to the students for post-test analysis.

> What the kids really appreciate is the discrimination. "You've got this one wrong and this one wrong and this one wrong." "I did?" From a student's point of view, we have underestimated how valuable that was for them. They really do want to know that and the immediacy of it immediately forces them to go back and look. They go back and they redo their test again on that basis, doing those questions and like it. It is a lot more positive situation. The immediacy of thge turnaround has been really, really good. So, from a student's perspective, it is nothing but positive that we've seen so far. No negative reactions to . . . communicating

their responses on a card. [#37:850]

For the teacher, the use of a card reader for test scoring entails an added workload as a programmer or as a technician if the operation is faulty. If the device performs as expected, however, release from a clerical task is the primary payoff.

> I can be spending more time preparing lessons or dealing with students. [#30:836]

Depending on the physical and supervisory arrangements in the school, some out-of-class time is implied if students mark the answer sheets.

> Generally, the kids that want to mark gladly give up their recess or their noon hour and come in and spend the fifteen minutes it takes, tops, to mark the whole class's work and then they are done for that particular day. [#37:975]

If, however, problems with the device are extensive, the teacher becomes more cautious of tackling new areas and may be content to hold the status quo.

> I am one of these people who are backing off, just don't have the commitment or the energies. [#05:470]

In summary, a teacher who is considering using a computer for test scoring, using a card reader, should know that

1) a dependable, easily operated device gives greater service to the teachers in the school for the investment, measured in tests marked per dollar spent,

2) the investment required for this use is dollars of school

capital funds and/or hours of teacher time (which could also come from school funds for release for program needs),

3) the teacher should be inclined to the process and limitations of marking-by-machine,
4) the interpretation by the machine of the student's marks is determined by reference to an arbitrary, adjustable standard of sensitivity, and
5) the students will learn that the device is not flawless and that unambiguous communication using the mark sense card is required.

Test Records The area of keeping records of student achievement is one which commanded both the highest level of experience (median = 2) and also the highest level of feasibility (median = 3) amongst the respondents to the questionnaire. Although four teachers were selected for discussion of aspects of this use, eleven other teachers referred to their activities here as asides to the primary topics discussed. In this use of computers, much of the differentiation between participants was dependent on the type of software that they chose. The programs used by the teachers ranged from a simple calculator function without storage of records, through programs suitable only for determining and storing marks, to multi-functional data management programs.

None of the programs required knowledge of programming. Most of the programs were "turn-key" requiring only operation of the hardware components and response to the requests of the menu-driven program.

The data base management program was operated as a learning activity by special project students under the instruction of a teacher and as a customized servicing of the marks of five teachers. The kinds of knowledge needed by the teacher encompassed both the large concept required by the teacher of the scope of the program as well as the details to be mastered by the student including

> how to operate the fields, which are the important things, the variables within the program. I will show them the various menu functions, how I can manipulate data. I will show them what I had done . . . using last year's programs. . . . The problem is that as you vary the teacher, you vary the format as well. . . . My format won't fit any other teacher's formats for mark calculations. [#40:390]

A range of computers including IMSAI, Apple, Commodore 8032, and LA36 DECWriter terminals to a mainframe were used with the marks records programs. No distinct advantage of any machine was noted except for a concern for the portability of programs between computers manufactured by the same company, e.g., Commodore 64 and 8032;

> I have to make some adjustments, so I have to go through and make sure where the problem comes in is where you are. With files, with the 8050, you are in Basic 4. Now I have to, with the Link in, I can have Basic 4, but I only have one disk drive. So with this particular program, . . . you put one disk in drive 0 and the disk that you want your file memorized to in the other one. The commands are specific for those different ones. So you have to go through and change those things. . . . I am hoping that is all there is.

> If there is more than that, then I will just scrap it; it is not worth it. [#35:178]

A proposal to process marks on a mainframe was seen as desirable by one teacher who hoped that fewer errors would result from direct reporting of the students' marks;

> We could directly feed the information that we have on these kids, their marks, to the Department of Ed. so that there is less likelihood for error. We went through a period of using computerized report cards a few years back; some schools still use them. We were absolutely amazed at how the mark-, the mark book with the bubble sheet, to some technician downtown, to the computer, to Edmonton, to the mail, and back to the kid-, how the mark could end up being so different. The amount of corrections and stuff was unreal. You could never place the blame anywhere; it was just a long chain and anywhere these mistakes were made. Now, we think it will be possible that . . . we could feed the mark directly . . . and once the teacher looks down the list and sees these are correct, that it will now be correct in final form. [#41:161]

The teachers learned about specific marks records programs by reading catalogs sent by publishing companies, by inquiring at local computer retail shops, and from local school system specialists. The programs that were used were produced by students or fellow teachers in the school where the programs were used, by a developer at the local University, by specialists working for a local Technology Institute or school system, by the Provincial Department of Education, by commercial software houses, and by the teacher-user.

For those teachers who were skilled or inclined to develop a marks program, that development was frequently

- a required project for a course,

> The only reason I wrote this one is because, with the correspondence course I took, we had to write a project. It didn't have to be as ambitious as the one that I did but I decided that's what I wanted; there wasn't one on the market at that time - or at least not a good one that I had seen - so I just decided to write one and so I came up with a useable one and it's mine so I use it. [#28:350]

- or because available material was unsuitable or inadequate for the teacher's purposes.

> Initially, I got started on it in terms of I just wanted a way of keeping a record for myself and then the school here had purchased a commercial program . . . it's not all that great a program. . . . The problem with it, and a number of teachers complained about it, was that you could only enter one student's name and you only saw one name on the screen. And it was on that approach that I started to look around. I played around with it myself and I was very displeased with it so I decided, "Well, maybe I can write something that will do what I want." And, as a result, we now have it set up so that it presents 15 students' names on the screen so it looks like a normal mark book. [#44:154]

The characteristics of the marks records software that were extolled were

- the flexibility of the data-based program,

> I purchased it realizing that it had a reasonable flexibility to do anything I wanted it to do, whether I wanted to do inventory, whether I wanted it to do students' marks, whether I wanted to do any kind of manipulation of any kind of data, I could do it with that Manager system. [#40+020]

- offering a format appropriate for the intended application,

> We tried it out here but it is designed mainly for a Junior High - Elementary, eight block a day-, more of a class-orientated, rather than an individual student mark sheet. . . . So what it does is . . . you would get all the marks for Grade 8 Health and then you would go on to a module in Shop and it would handle all the kids. And it wouldn't look at what this kid was taking if he switched courses all the way along. . . . Again, it is very awkward to use in the High Schools so we

> decided not to go with that one either. [#09:081]

- the operation of a program from a single disk drive,

> But it's not that good; it needs two disk drives and I find that teachers really don't like a two-disk-drive system for their marks because they like to have it all on one disk. They want to have their disk with the program and their files on the same disk. . . . They have control over it. [#39:120]

- the rapid and efficient processing of marks,

> That was an experimental program that we decided to try up until January and then we gave it up because it was too cumbersome, too time-consuming-, access to individual student information, to enter marks, retrieve information-, it simply took too long. [#09:060]

- provision in the program for requirements of the teacher,

> Problems . . . in weighting factors in columns and marks. . . . "Will it handle anything less than 5%? Will it handle anything over 5%?" He hasn't done that in his main program. If it is less than 5% for each column, it won't touch it. . . . So you have got to watch yourself, so that when you are doing a kid's average, I always check to make sure that if I do one kid's average, and if his is right, then the rest should be right. [#09:699]

- the thoroughness of the manual to describe the limitations of the program,

> I am not sure that they could write a manual that defined what I wanted to do . . . so I can carry it off right away. . . . To do my function of reporting, I think one has to be a bit tolerant of the fact, maybe, they weren't writing a manual for doing report cards [using a data-based management system.] [#40;+122]

- the ability of the program to gather and weight similar marks for a final summary,

> I have used the one written by our student; I'm not happy with it, and I will tell you why. Because in the Sciences, I like to usually allot 10% for Labs, 20% for the Final Exam, that is the way we used to do it, and 70% on classwork. This program did not facilitate this. [#35:163]

- and allows adequate description of marks.

> But it wasn't giving us, for example, if I would type in Test #1, I would type in T1. When the student gets back the printout, it says T1 50%. He's got to go back to his own records, unless I provide them, to tell him what T1 was. With Compumark, we have available, at the bottom, a legend. T1 was Test #1 on Reaction Kinetics; L2 was Lab #2 on Precipitation Reaction; and so on. [#42:242]

The difficulties that were experienced by the teachers included the phenomena of

- working with the requirements of the computer/program

> The only part of it that is a little bit of an inconvenience is the fact that before I can enter it, . . . I have to get a mark for each of the students. Now, there is a provision in the program - I can go back and add or change a mark for an individual student but it's a little bit of a hassle to do. You have to start up the computer and you have to go through certain procedures to change the one student so it's easier to wait until you have all the marks for the class before you enter it. [#28:331]

- and coping with the workload associated with this use.

> It does take time on a weekly basis perhaps for us to enter the marks, but again, it is at a point now where we have one or two students who we say to, "Look, I've got a new set of marks, would you enter it for the class?" . . . They love to be helpful and so they'll do it for us. And it saves a lot of time. [#42:31]

The teachers, as they encountered the difficulties described above, called upon a number of resources ranging from their own perseverance, their friends or colleagues, or the author/manual.

> For this particular program, having gone through it once with Cam [the author], all staff members present, was enough to get people with it, and ready reference to the manual. The only thing we have done is, as we have used it, we have simply made notes here and there.

[#42:27]

The limitations or impediments to good teaching practice detectable in the comments by the teachers related to

- the perceived infallibility of the computer's printout of marks

> The administration, they belief that the computer can't make an error. . . . If I give them a computer print-out, they take it for face value. Then they don't look at my record book and they don't think. [#27:1138]

- and the confidentiality of posted student marks.

> I asked the students prior to ever posting anything like that, "Look, are you opposed to the new way of having your marks presented to the rest of the class via the bulletin board at the back of the room?" I haven't had any students object. I they did, then of course, I would consider some way of removing that particular person's mark, just by blanking it out from the printout, cutting it out of the page, or whatever, or making other kinds of personal adjustments. . . . The names are there, the marks are there. Students can see how many assignments they have, who's missed them, who hasn't, what grades you're getting, what the average mark is on each assignment as well as the overall class mark. [#42:32]

The impact of the computer on the teacher's common chore of recording student achievement was felt in three areas;

- the potential for relief if the teacher is released from the task of data-entry and manipulation

> It is a very mundane act, particularly if you have any broad evaluation basis. . . . I find it extremely tedious, I can think of nothing I'd rather-, I don't enjoy it. [#40:+224]

- the practice of teaching,

> Because of the time-saving feature and the immediacy of the feedback, I probably now provide more hard evaluations for the students than I would have otherwise. In other words, there may be more quizzes, there may be more assignments that are handed in for grading, and the results being given back to them. [#42:33]

- and the relationship between the teacher and other persons.

> It certainly has speeded up the process of assigning marks and keeping track of a grade, and giving instant feedback to the students and/or a parent. [#42:26]

The effect of reporting marks using a computer is as significant for the student as it is for the teacher because, when marks are calculated and posted,

- self-improvement is noted,

> The kids respond very positively and they can see, "Well, this test has pushed me up, pulled me down, where it has . . ." [#44:096]

- and teachers are shown as accountable for their role as processors, and not originators, of students' marks.

> I think we are accountable to [the students.] "Those are your marks, not my marks. You are responsible for those things. I had better have done my job right." I think that probably the hardest thing to get used to is handing these things out and "There is what you have done, as I perceived it, and I marked it, and I corrected it. Am I right? Did I make a mistake? Did I do something wrong? And, if I did, then I think that you have more than a right to talk to me about it." [#40:889]

In summary, a teacher who uses a computer for mark records should know that

a) this function will magnify or enhance those same activities (recording, compiling, reporting) that the teacher would have completed without using the computer,

b) the limitations of the program or computer in executing these activities must be identified using trial data,

c) there will be a trade-off between increased clerical activities of entering the data and decreased calculations in processing the data, and

d) an examination of the issues of confidentiality and accountability should be made prior to using the computer's ability to expand the reporting of marks.

Test Item Analysis The extensive use of a computer for test production and mark records is strongly contrasted with the negligible experience (median = 0) and moderate feasibility (median = 2) when used to aid in test item analyis. Four respondents contributed the comments that are compiled in this section.

The programs that the teachers used were SuperPilot, a program for the Chatsworth card reader (both programs used on an Apple computer), and those written for the mainframe computers operated by two large urban public districts. The teachers had not used any knowledge of programming for analysis of test items. However, to initiate the analysis of test items using any of these programs, the teachers needed to follow directions either from the screen or from the manual accompanying the program. Neither students nor teaching aides were involved but the use by the teacher of the statistics provided by the program required an extensive knowledge including

- the extent of the information that is to be selected from the printout of statistics,
- the significance of the statistics that are produced by the program,
- the criteria to be used to evaluate the statistics presented, and
- the techniques for revising questions using the statistical information.

The analysis of tests used by the teachers in this survey employed hardware and software that had been selected either by other school personnel or for other purposes. The analysis of test items was then a supplementary benefit that was used only occasionally,

> We're not using it as extensively now as we have in the past. . . . So, a number of times during the year, . . . I think we're running about four a year. This year, for example, I think we've only sent in two, but we did a few more last year which means that in the rotation, we're a little bit more confident with more exams that are still up-to-date. [#46:054]

The major use of the test statistics by the teacher was for building and revising tests.

> What we're trying to do is build a bank of tests rather than just items that have been through everyone else so, as the years have gone by, we have done that. So we use the service now when we're trying to put in a

new test. [#46:000]

Features of the analysis section of servicing tests that were identified as useful by the teachers included

> It gives a frequency response to each of the possible answers, . . . a distribution frequency of the scores - how many people made the scores. Then it gives a mean and a standard deviation . . . [#05:211]

> The question is defined in terms of what the classification is - Knowledge, Comprehension, Open-Ended, whatever - so you have that classification. It's also got a level of difficulty associated with it. [#44:712]

The teachers used the computer-generated statistics for test item analysis when new questions or tests were being constructed or evaluated.

> If it was a test constructed by the teacher and he was interested in doing that, I think it would be helpful, you know, it would at least get him in the right ball park. [#05:211]

The revision of test items on the basis of statistical analysis was done initially by a revision committee but in practice by an interested individual teacher.

> With the revisions, we tend to do it together . . . You just have to take this test and I'll go through it because we just can't get people together, unless the person has a particular interest in the test, then often they'll do it. The ecology test we had some years back, for example, I did because I was keenly interested in that and we just couldn't get together. [#46:084]

The impetus for constructing, testing, and revising test items came from a sponsoring institution such as the employing school, school jurisdiction, Department of Education, or from the individual teacher.

> I think it has a lot to do with the fact that, as science teachers, you have some feeling towards objectivity and that if there is a way to check and see if a question is perhaps being objective enough, you are going to utilize it. [#46:017]

Although the statistical analysis supplied by the computer was useful, the teacher and the pupils are important sources of information to assist with test item revision.

> If someone was wondering about starting this kind of service; in itself, it's very useful but I wouldn't want to do it without always having the thorough experience, when going through a test, of having gone over that test with the class that wrote it. . . . Especially when you go through multiple choice examinations with students and hear their objections to certain things that - I'm sure you've experienced this - there's no way that you would have seen that until you went through it with a group of kids and they said, "No, but I thought this meant something else" and you look at it and say, "Well, of course, you could read it either way!" [#46:147]

A difficulty frequently expressed was the delay in processing the test results using the mainframe computer to produce the statistical results.

> I think I remember doing it once and the turnover was so long. [Pilot]

In summary, a teacher who would use a computer for analysis of test items should know that

- there are many levels of information released by statistical programs and each level is appropriate for various degrees of revision of test items,

- several souces of information each bring their own information and perspective to the test items that are under scrutiny,
- instruction in how to use the information presented in the statistics, mastery of the course content, and an understanding of student learning behaviour are all necessary to achieve the desired, revised item,
- a dilemma is frequently presented between using delayed, extensive results available from a central mainframe computer and less detailed statistics from a local school microcomputer.

Mark Trends Teachers in the survey had virtually no experience (median = 0) and only moderate interest (median = 2) in correlation of marks and analysis of trends. Only one sixth of the respondents indicated some experience or interest and, due to time limitations, only one of these was interviewed.

The interviewee had not used a computer for analysis of mark trends but had done an elementary analysis as a response from administration personnel.

> A few years ago, there was some exam written. . . . Everyone writes it and then, of course, analysis of marks is done in some fashion and typically we'll get information back to the school. They'll have, say provincial average such-and-such, your school average such-and-such, and then the question, say from the

> person at Central Office, will be, "How do you interpret this?" Maybe we're four percent below provincial average. My initial reaction to this was one of a little dismay. [#13:25.9]

Concern was expressed for a balanced view of the measure of productivity of a class,

> I am not sure that I am terribly interested in a lot of detailed statistical analysis of an individual class of mine. I think there are subjective aspects to this that might be more significant than the objective. [#13:27.1]

and a need for training of personnel responsible for interpreting these statistics.

> I don't like necessarily getting involved with that kind of detailed analysis because I really don't know what it means in any case. . . . There are so many different ways of interpreting data anyways that - from statistical standings - that I am not sure how important I feel that is for an individual class. If they take global views of many tens of thousands of students, there may be some interest in that kind of thing. On an individual basis, I don't know. I personally wouldn't be that interested in it. [#13:27.2]

The onset of diploma exams, the capacity of computers to store and analyze data, and the tendency for work to expand in proportion to the opportunities that are available predicts increased activity by school personnel in this area of analyzing, or responding to analysis of, trends in marks.

> Alberta Ed. is doing it right now. We are going to have to react to that in some way or another. . . . This whole thing is broadening out now . . . I think, whether we like it or not, we are going to be forced into this kind of item-by-item thing, "What are the trends in this particular area? How are the exams being modified to compensate?" To me, it is a very complex and very messy situation. [#13:26.4]

A final observation was made that the use of computers for this purpose is for supervisors or coordinators and not for the classroom teacher.

> Whether we will be able to do anything meaningful in a small sample within the school, I don't know. It always distresses me when people complain that a school or a kid is below average, because, by definition, half of the population is below average. The next year, maybe we're four percent above average. What does it mean? It means absolutely nothing on the face of it. I don't know what you were actually getting up there, but this becomes really an administrative, supervisory use. [#13:26.6]

Career Guidance Although career guidance tied with gaming as the lowest ranking use of computers by experience (median = 0) and feasibility (median = 1), nearly one third of the respondents indicated some aquaintance with this use and two respondents described their activities.

The programs that were used for this service to students were data banks of occupations, the search of which was controlled by the responses to questions asked of the students.

> The one that we have is a program that I believe was developed by a guy in Rocky Mountain House. It is commercially available. All of our high schools have a copy of this. . . . What it is is a listing of approximately 800 to 900 types of careers. It leads a person through making choices of their interests, their abilities, what kind of wages they would like to have, and I don't know how many questions there are. [#24:262]

The programs were menu-driven and required little assistance.

> Now, for orientation as to how to operate the hardware, I think it is almost nothing, really, because the . . . disks are inserted into the machine permanently. It has got a great big piece of tape over it so that you can't take the disks out. . . . It is completely menu-driven. You just follow the questions. The kids find it very easy to follow the questions. They don't get into trouble - except occasionally. . . . Any teacher, or any student, can be trained very quickly to go through the proper order of turning things on, and slipping disks in, and being careful of the little red light and that type of thing. But there is a little bit of training that is involved, so that it is more than just turning it on. . . . Usually the guidance counsellor will be there when the student initially starts on the program, just to make sure that they get in properly. . . . The counsellors take them, and then, more or less, they give them the code to get in. [#24:332]

No programming knowledge was required by either staff or students.

Both teachers were in schools where the guidance department had fiscal and managerial responsibility for the service. Guidance staff handled all arrangements for booking and booting the computer.

> The guidance computer is not available to the school other than for the guidance people. They have made that very clear to us. [#24:353]

The schools used Apple and Commodore computers for this guidance service.

- The selection and maintenance of these machines was done by the department,

> As far as I know, the hardware was given to the school. Now whether it came from the School Board or from Alberta Education, I am not certain. . . . This is the reason that the guidance department is very protective

> of the hardware. [#24:686]

- as was the selection of the programs.

> [The counsellor] has looked at CHOICES, spent two days at a camp, and I think [the Factory author] is going to come down and spend another day with us so we can get a pretty good look at it. [#09:864]

Only two programs were used by the schools, CHOICES and Career Factory.

> Career Factory appears to do the same thing that CHOICES does, except it is cheaper, and it is handy to us. [#09:864]

Prior to using the computer, the students were given a list of expected prompts to which they wrote their anticipated responses.

> One thing they have to do before they get on the computer itself, the counsellors have a piece of paper which takes [the students] through a lot of the questions ahead of time and they are asked to fill out those questions on a piece of paper so that, when they come to the computer, they can respond reasonably quickly and have an idea as to what kinds of questions are going to come. [#24:332]

Because the teachers held dual roles of science subject teacher and student advisor, they were atuned to the benefits of this use of computers by science students. Using the program was considered to indirectly benefit the teacher and the student;

- the teacher, and hence the students, received additional background about the practical applications of the subject matter of the science course being developed

> I will be talking to kids about vectors or something and they will say, "Well, what good is this going to do us?" And I will say, "Suppose you think ten years down the road that you might be out in the country someplace, in some hick town, but your big interest has become flying." And they will say, "Well, what does flying have to do with vectors?" I said, "Yes, I've taken a few flying lessons, I know that vectors have a lot to do with it when you get down to the maps . . ." You just keep on listing examples, so they finally get the connection between the two. It is very incidental, it is not that I go into class and say, Well, I'm going to tell them everything that is practical in this course. It just comes incidentally. [#09:915]

- and it was possible to identify the relevancy of the course content to the students' post-secondary plans.

> When part of your teaching and part of your course is talking about the applications of the course and technology, it would be nice to have a nice, big long list of careers that sort of fit into your chemistry course that you have. Now what can a person do when you get out. A lot of that, I've just gone on past experience and I think that perhaps that Career Factory or something like that would be a help. [#24:315]

The impact of this use for science teachers is that the teacher is assisted in bringing the student to see that the learning of the course material is part of their whole life experiences.

> I stress in my Physics class, I say, "Go out and get an Engineering degree; if you can't make up your mind about anything else, at least try that. If you get accepted and you put in a couple of years maybe, by that time, your eyes will be opened up a little bit. Get a little bit more experience in this thing than we can at school here." And we are sure trapped, really! You don't have much outside contact, but you do at least once you are out of here. That is one of the big drawbacks of counselling; you are here. You are not in the main flow, main stream of things in the business world. So whatever I see as being a good job gets passed onto the kids. Maybe one kid picks it up in so far as counselling; in that sense, that is what I am doing. I imagine that is what some of the other teachers are doing as well. Depending on what courses

> they take, you are going to get influenced by those teachers to a certain extent. [#09:888]

Summary

The vast amount of data provided by the science teachers during their interviews was progressively sorted by phase of teaching activity, type of computer use, and category of knowledge and skill to give a description of the specific knowledge and skill needed for integration of computers into the science curriculum.

CHAPTER V

The Knowledge Perceived as Needed by a Teacher to Use Computers Effectively in Teaching Science

Introduction

The knowledge and skills possessed by a teacher are cumulative over various past events. These separate experiences are usually integrated into a whole understanding stronger than the individual ideas. The same can be said about the use of computers in teaching science. In this chapter, various ideas and practices are brought together to form a composite picture which, hopefully, is stronger and more useful than the individual parts. The information used for the synthesis comes from three sources:

- the survey of references and periodicals (Chapter 2),
- the results from the questionnaire and the structured interviews with practicing science teachers (Chapter 4), and
- the related professional experiences of the researcher.

The researcher believes that these three sources are fairly exhaustive in presenting the "state of the art" of using computers in science instruction. By selecting correlated observations and unique comments from these three sources, a description is synthesized that describes a possible introduction to being a computer-literate science teacher.

In a manner similar to the way the knowledge requirements for each use are built into a unified whole from the separate information sources, each interviewed teacher formed a coherent, working pattern of behaviour in computer use that was consistent with the educational values to which the teacher subscribed. Crocker (1983) suggested that this pattern, which he designated as the teachers' "functional paradigm", was build on common beliefs, values, exemplars, and routines. Lantz and Kass (1987) identified, as elements in the functional paradigm of chemistry teachers, four common perceptions by chemistry teachers of: high school chemistry, teaching, students, and the school setting.

In this study, the common elements that were present in the functional paradigm of the interviewed science teachers appear to be the five categories of general knowledge in computer use that were identified in the questionnaire responses and around which questions were posed to the interviewees to identify what a teacher should know about computers to use them effectively (Appendix H).

One factor in the functional paradigm of the computer-using science teachers that was noted in passing is the effect on the nature of the science instruction as a result of using the computer. The interviewed teachers indicated that this influence was already being felt in various uses and phases of teaching. Although the technology presents potential for improvement of instruction, it may also mold the direction and emphasis in instruction in ways that may or may not be considered desirable. For example, test-item banking with emphasis on multiple choice items may be a great time-saver for the teacher, but it could also result in the neglect of evaluation of (and hence instruction for) important outcomes in science.

This chapter is organized as follows: In the first part, there is a brief critical re-examination of the framework for the study, as represented in the questionnaire in Appendix A, on the basis of the data gathered from the teachers. This is followed by a presentation of the general background knowledge that is required for many, if not all, specific uses. Finally, each of the uses remaining, following the critique of the framework, is discussed in detail on the basis of the three sources of information indicated above. This is done from the point of view of helping a teacher understand the specified use, the kinds of objectives that might be achieved in science with this computer use, and, finally, how the teacher might get started in the use and ultimately become effective with it.

A Critical Examination of the Framework

The structure of the questionnaire in Appendix A is one representation of the framework used for identifying and defining computer uses in science. This questionnaire resulted from the literature survey reported in Chapter II and the pilot stage for gathering data from teachers discussed in Chapter III. The validity of the framework now must be judged in terms of the data obtained from the teachers in the main stage. These data point to the following considerations:

1) The three phases of teaching activities constitute a useful sequence for classifying the specific uses of computers in science; hence, should be retained.
2) All eighteen uses spelled out in the framework are legitimate possibilities. However, they are not all deemed to be equally important or feasible. For example, at this time, very little of real value for the study can be said, from the perspective of the teacher of science, about the use of computers in career guidance, hence, it is now dropped from the list of uses discussed in this chapter. Others, such as the use of computers in professional development, have not been developed yet or become an actuality, but their potential value is so great that they will be included in this chapter.
3) Some of the definitions of uses need to be modified and/or elaborated. This is done at the beginning of the discussion of each use. For example, "library applications" has been expanded, as "information retrieval", to include all instructional resources in the

library instructional technology resource centre, laboratory supply rooms, etc. In a contrary fashion, the description of "simulations" has been restricted to include only applications of modelling of phenomena leaving the other, previously included, laboratory-oriented application as a separate use as "experimental analysis".

4) Very few, if any, of the uses described in the framework stand alone, unrelated to any other use. Indeed, the opposite is true. For instance, a computer program that introduces new content in a tutorial mode might also incorporate drill and practice as well as simulations. However, the eighteen uses remaining in the framework are distinct, as can be seen from their definitions.

5) The framework did not recognize the general background knowledge that underlies a number of specified uses. This knowledge represents a body of information which could be considered prerequisite to most subsequent uses of a computer and, rather than repeat this general knowledge under each use, it is dealt with in a separate section below.

General Background Knowledge

The results of the study, partitioned in the previous chapters into the various phases and uses, identified several categories of knowledge that were in common or were compatible across several uses. These are as follows:

operating and programming, hardware and peripherals, software and courseware, word processing, inter-computer communication, implementation of applications, and impact on the teacher.

The purchase and operation of a computer system in an educational setting has several requirements regardless of the timing of the proposed use in the cycle of teacher and learner activities. The common factors identified below represent a possible core of knowledge for a computer-literate teacher.

Operating and Programming

The common body of operating knowledge needed by the teachers is limited to that which would be considered good practice and able to be learned in a brief orientation session, including the practices of

- care, handling, and loading of the program disk,
- adjusting the monitor and printer for operation, and
- responding to menu prompts in the program.

Programming knowledge is, in general, not required for the computer uses described. However, for even the most superficial application in any of the uses, a knowledge of the components and stucture of the program is desirable so that the purpose of specific integral activities can be understood. For the user who intends writing simple programs or customizing programs written by others, an introductory level of a programming language is necessary. BASIC, notwithstanding its limitations of machine-dependent dialects and slow speed, is preferred because of the presence of this language in the ROM circuitry of most microcomputers, its simplicity, and its pervasive use in common programs. The initial set-up of the computer system involves the technical knowledge of electronically connecting the components of the computer system, and often, where a printer is required, entering control codes for special print effects.

Operation of the computer using alternate input devices, such as trackball, mouse, touch screen, and light pen, each have their own operating advantages and limitations for particular applications (Poor, 1987; Rose & Wisell, 1987, Stone, 1987). Also control of the computer by voice commands and by stare-at-the-screen-and-blink for the physically disabled users are possibilities that are currently under development.

Hardware and Peripherals

The selection of the computer and specific peripherals, such as, printers, screens, modems, and alternate input devices previously listed, is chiefly dependent on two factors, viz., a) defining the nature of the problem to which the computer system has the potential to be of assistance and b) assessing the level of support that the teacher can call upon in bringing the computer to the task of addressing the defined problem. The actual entry of the computer to the science classroom is predicated on the availability of financial resources for the purchase and suitable software for the intended use. Within these constraints, the interviewed teachers identified general features that rendered a particular computer system suitable, including

- the availability of quality, local service facilities for user support and hardware maintenance,
- the extended presence of this model in the education field with a record of performance and reliability,
- its capacity for upgrading the operating language, peripherals, or software for applications or other uses not perceived in the initial proposal for purchase, and
- an appropriate visual display on the monitor, e.g., high resolution for graphics, monochromatic for word processing, large size for whole-class activities, color for motivation or clarity for learners, delivery to a television for low-budget service.

A teacher should also weigh, when considering the purchase of a variety of hardware components from different dealers, the

- merits, such as reducing total capital costs and optimizing performance characteristics of equipment, and
- disadvantages, such as achieving electronic compatibility and resolving component faults for servicing by dealers.

One concern relative to hardware (and software) purchase that was frequently identified by the interviewed teachers was the need to purchase state-of-the-art machinery. However, in the rapidly developing area of microprocessing equipment and programs, the identification of this 'best of the lot' changes annually. Thus, significant advances have occurred in the capabilities of both hardware and software since the teachers were interviewed. These changes bring with them revisions to the learning requirements of computer-using science teachers. For example, larger memory capacity had all but removed the need for chaining text files for classroom tests. Word processing programs now commonly provide for drawing diagrams; how does the teacher utilize this feature? However, the large purchases of computers in past years may have created an impression of adequately equipped schools that may tend to discourage purchase of these more powerful computers and their programs. Thus, although the equipment and programs are available, learning requirements won't change much unless the new hardware and programs are adequately provided.

Of considerable significance for good management of both finances and the classroom, was the identification by the teachers in the study of the optimum number of computers for the intended uses. For example, only one computer was required for all Phase I (Preparation for Teaching) activities, electronic chalkboard applications in Phase II (Teaching/Learning), and all Phase III (Testing and Evaluation) applications unless the computer supplied tests directly to the students. For this direct test administration, the number of computers needed depended on whether the student carried the printed test to a work site or answered the test at the screen display. Computer requirements for most Phase II (Teaching/Learning) activities, estimated by the teachers in the study as one-half to one-third of the number of students in the class, would allow for simultaneous, alternate desk or laboratory activities. Some applications, e.g., test administration in a "lock step" curriculum program, will require a number of computers equal to the size of the largest class.

The interviewed science teachers also described their need for access by their students to the school's computers on an equal basis with other subject area users. They also underlined the desirability of having a computer in the teacher's home for work, primarily in Preparation and Evaluation applications, at a time and pace not controlled by conditions present in the department office, library, or staff room.

Software and Courseware

According to the interviewed teachers, a teacher considering a purchase could probably learn about software programs by reading evaluation reviews or by critically evaluating advertisements in periodicals, by discussing the merits and disadvantages of specific programs with colleagues, or by observing demonstrations given by distributors or workshop leaders. The Clearinghouse from the province's Curriculum Branch provides regular, thorough evaluation reviews, open-house preview opportunities, and purchase information for prospective computer program users. The programs could be purchased either from a local distributor or directly from the publisher or be loaned for examination purposes by an associate, a common practice amongst the interviewed teachers.

A teacher who intends developing a program could proceed either as a solitary designer/programmer or could participate as an individual (or with other professionals in a peer network) to design the program and assign another person to write the code that satisfied the specified requirements. Motivation for this private development would be necessitated by the lack of suitable commercial or public domain material and dependent on the availability of time for writing a usable program.

The primary reason for a novitiate incorporating a program into the school activities would be the enhancement, for the teacher or for the students, of a normal classroom activity. The acceptance of any program is based on its ability to perform the functions that are expected and the ease with which the program can produce the expected output with a minimal amount of time and manipulations by the user.

Word Processing

Word processing programs comprised the largest list of non-course specific programs used by the science teachers, according to their questionnaire responses (Appendix C). Used primarily for Curriculum Planning and Materials Preparation and Test Production, and to a lesser extent for Professional Development and other Phase I (Preparation) application, they reflect the extent of the teacher's creation of the printed message in the teacher/student/course interaction. Mastery of a word processing program, as part of a fundamental level of computer literacy, also offers teachers an additional bonus of being able to use this skill for non-school related correspondence, thus increasing the payback to the teacher for the time invested in learning to operate the computer/printer/program system.

Word processing programs consist of a set of procedures for receiving, organizing, and displaying information in a printed form. They offer standard features for handling text material, including, entering, deleting, revising, inserting, finding, replacing, merging, copying, moving, saving, and printing blocks of words. The teachers in the study indicated that using a word processing program enabled them to

- reduce their typing to only initial-entry efforts, an advantage for slow typists,
- be less dependent on school support staff, a limited resource in many schools, and
- revise existing files to provide a context for materials which reflects current pedagogical concerns or class interests.

The textual material as it appears on the screen may be, depending on the specific word processing program, displayed either exactly as it will later be printed or it will show both the characters to be printed and the symbols (control characters) that represent formatting commands to the printer, such as, boldface, centering, superscript, margin sets, justification sets, pitch, line spacing, etc. A science teacher who is using a word processing program will also need to know the capability and operation of the program for placing diagrams, graphs, sketches, and user-definable characters amongst the conventional textual materials.

Lastly, and yet one of the essential steps to be taken before purchasing and learning to operate a word processing program, the teacher will need to assess the levels of both the resources (time and financial) available and the production requirements of the task to determine the level of complexity, from Write One to Gutenberg, of the word processing program (Wright & Forcier, 1985).

Inter-Computer Communication

A number of the uses described in the framework require, at times, a hook-up by means of a modem and a telephone line between the teacher's computer (at home or at school) and another computer, usually physically distant. These uses are as follows: Curriculum Planning and Materials Preparation, Professional Development, Communication Between Schools and/or Teachers, Information Retrieval (formerly Library Applications), Tutorial, Drill-and-Practice, Test Production, and Test Item Analysis.

When a teacher uses a computer connected through a modem and a telephone line to another computer, one of three possible modes of information transfer are possible. The simplest possibility, used by an interviewed teacher during his orientation to the use and existing when two microcomputers are linked, allows simultaneous operation of the "called" computer under the control of the "calling" computer, thus enabling the accessing and running of programs from files on the disk of the called computer.

A limitation on this simplest case, that both computers must be powered on at the same time, is circumvented when a third computer acts as an electronic "bulletin board", where notices can be posted and addressed to specified callers for later reading as "electronic mail" or to select groups of interested individuals, resulting in a "conference" where each caller is able, at a convenient time, to read and add comments about a commmon topic.

A third possibility for computer/modem communication is when the called "host" computer has a large library of information that can be received by the calling computer. Several of these "data bases", such as The Source, CompuServe, Dow Jones News/Retrieval Service, and Dialog, dispense information on a wide variety of topics currently of consumer interest. The educational equivalent, E.R.I.C., provides rapid identification and access to abstracts of documents and articles in periodicals of significance to teachers. The computer may also be used to "download" a variety of computer programs from a central mainframe computer, including

- curriculum print materials for teacher or student use,
- instructional programs including tutorial and drill-and-practice sequences, and
- selected test items for a teacher-designed test.

Benefits of storing materials at such a central facility include the

- ease of revision of the master copy of the materials and programs (Merrills, 1982),
- possible reduction of total costs by district licensing of the courseware, and
- easing of the necessity for all schools to hold large, virtually identical inventories of computer programs.

The knowledge recognized by the interviewed teachers as necessary to operate the computer in any of these modes of inter-computer communication consists of

- knowing what systems are available, and their telephone number, for the mode of contact that the teacher requires, e.g., mailbox, conference, or data base,
- knowing how to access the host computer,
- being able to identify oneself by name or assigned identifier and, usually, a password, and
- being familiar with the significance of, and using, the options usually presented in the menus of the bulletin boards or data bases.

Because the host computers have both varying kinds of services offered and interconnections with other agencies, a degree of sophistication is required to maintain control of the activity.

A knowledge of programming is not required if a software program has been purchased for communication via the modem or if the microcomputer is to be used as a "dumb" terminal with no files being sent or received and stored. Knowledge of possible file formats and handling is needed if programs or data are to be sent or saved. The extent of the technical knowledge that is required is for the initial setting of the modem's circuits to format the electronic signal to be passed in a form that is recognizable by the transmission network, if used, and by the host computer.

The peripherals required to enable inter-computer communication are a modem and a serial communications interface, if not part of an "internal" modem or supplied as part of the computer. Most host computers display 80 columns of text and thus an 80 column card is usually required for the microcomputer.

Before purchasing a communications package, a teacher should ensure that

- an operator's manual, both tutorially and technically adequate, is included and that post-sale support and service are available,
- the modem and serial interface card and the interconnecting cable are wired to function as an integral unit, and
- the modem and screen display have the capacity to function within the parameters set by the systems to be accessed.

Because of the nature of the non-moving electrical components in the modem and the card, service is not ordinarily necessary after the initial shake-down period of a few days; service by the owner at any time is not recommended by telecommunication authorities.

Most computer/modem systems can function as a no-files-transferred "dumb" terminal without an operating program. One of the main benefits to be gained from using inter-computer communications, however, is the ability to send and receive information that is or can be stored as "text" files on a disk. According to the interviewed teachers, a complete telecommunication system should, therefore, be able to

- convert outgoing files from BASIC or binary into text

files for later transmission and to similarly convert incoming text files into a usable form,
- decrease "on-line" time and charges by holding information in memory until the teacher elects to send the outgoing file or to save the incoming file on a disk, and
- edit the file in the memory.

The data-handling program can be either permanently sealed in the circuitry of a "smart modem" or it can be loaded from a disk each time the teacher decides to use the telecommunication activity. Telecommunication software for most microcomputers is available from local dealers.

The rapid, world-wide transmission of news, the shopping directories in malls, and computerized booking for travel arrangements have made most people aware of telecommunicating with data bases. The lack of a visualized source of the information will, however, make this implementation difficult for beginners (Sevel, 1984). Thus, for initial exposure to this activity, side-by-side inter-computer communication and repetitive easy access to a conference board and to a data base, such as a test item bank, will be needed. Clear documentation, a short summary of expected commands, resource personnel, and on-line help are required by the teacher. The teacher also must have access to the computer and modem at convenient times and places (Brochet, 1985). Inter-computer communications will have to be shown to be able to meet a perceived need of the teacher before that teacher will consider investing personal or professional time in this somewhat impersonal media. The interviewed teachers indicated that they would not participate in an electronic mail facility until a "critical mass" of their peers are also active participants, thus assuring origination and reading of messages. Thus, widespread implementation will begin with close groups of teachers with common, binding interests that function as a primary focus while their computer literacy skills are being developed.

Implementation of Application

According to the interviewed teachers, introduction of the computer as a possible medium for a particular use comes frequently from the example given by a colleague, the presentation of the possibility in periodicals or advertisements, or the perception of a possible adaptation of an established operation in existence at the local school level.

After the teacher has become aware of the possiblity that the computer holds, the next stage requires that the teacher must perceive some value in the computer's use. Some interviewed teachers used the computer to

- motivate or give variety to the student's routines,
- increase the relevance of the course material to the student,
- reduce the amount of drudgery in the students' classroom

activities,
- open new possiblities for meaningful educational experiences of the students, and
- modify the teacher's professional workload.

The implementation of the computer system in the intended application should follow a path that includes
- familiarization with the system by "hands-on" pre-purchase testing of the system and reading of the operator's manuals,
- validation of the system by the application of the program to a situation that is familiar to the teacher where the outcome of the program is verifiable or significant, and
- probing for the limitations of the system by testing with difficult values or entries.

Frequently, the introduction is eased by recourse to a one-page summary of the commands or to a knowledgeable colleague.

Difficulties experienced by the teachers can be expected to come from various directions, such as
- limited access to equipment or programs because of budget difficulties,
- the modification of the curriculum or the established classroom routine by the introduction of this media, or
- the difficulties in achieving the desired output from components of the system because of limitations in the original design of the software or hardware.

The support system to which a teacher has recourse includes, in varying degrees of proficiency,

- school system consultants for inservicing,
- school administrators for funding,
- experienced colleagues of the teacher for models of computer use,
- professional specialists' associations, e.g., Computer Council, Science Council, for curriculum-related applications,
- capable students within the teacher's circle of aquaintances for programming and operating tips,
- users of computer bulletin board systems for assistance with operation of programs, and
- technical staff at local commercial dealers for trouble-shooting techniques.

In this study, the focus on 'what the teacher should know to use the computer' may be construed as promoting the multi-dimensional talents and skills of the all-purpose science teacher. However, effective use of computers must also recognize the benefit of support services such as subject area consultants, repair service facilities, classroom aides, etc. Utilizing these personnel will remove from the teacher the need for specialized knowledge that is expensive, in terms of time and training, to acquire and that is only occasionally used by the individual teacher. Partitioning of responsibilities for computer implementation in the school would thus allow for more efficient concentration by the teacher on dimensions relating to effective computer use in the teachers' primary work area, the science classroom.

Impact on the Teacher

An initial effect on the teacher of using a computer across most activities was the need to achieve a balance between the challenge of exploration of a new area of study and the maintenance of current programs. Along with the exploration comes an allocation of time. The interviewed teachers described the realization, at some stage, that a point had been, or would be, reached where further investment of time would not substantially increase the benefits for the teacher or the students. Thus, a mental balance sheet of time invested and time saved was monitored.

Another effect was the intensification of the dual role of the teacher as an independent learner and the teacher as a member of a supportive community of learners. Most of the teachers proceeded on their own path of implementation but occasionally touched base with others for assistance and comparison of progress or new ideas.

A third effect is that the teachers will come to re-evaluate their role in the classroom as the computer is assigned tasks that were previously assumed by the teacher. Facilitating student learning activities rather than lecturing was a frequently cited change. Diagnosis and assistance with individual student problems requires new skills when students are working at various stages in a computer program or on different instructional activities.

Changes in student activity brought with it new patterns of student behaviour and thus reexamination by the teacher was required of his(her) expectations of normal classroom management (Olson, 1986).

Knowledge Needed for Specific Applications

In addition to the general knowledge described above which is necessary for entry into most of the uses, more specialized information is required for many of the uses in the various phases of a teacher's professional activities. This last section of the description of what a teacher needs to know is divided into the three phases and the eighteen uses formed from those in the questionnaire in Appendix A. Each use is discussed under the following sub-headings: definition, rationale, implementation, and illustration.

Phase I: The Preparation for Teaching

The potential for computer assistance to teachers in the preparation for teaching is extensive, ranging from accessing data banks of information to preparation and storage of materials using word processing programs and planning student progress in a course of studies.

Curriculum Planning and Materials Preparation

Definition The preparation of instructional materials and storage in files, the display of these materials for preview and selection by the teacher, and the printing for student or teacher use serves an important purpose in the preparation phase of a teacher's professional activities, whether for worksheets or notes, whether in a mainframe memory or diskette based.

Rationale The textual materials for a school course usually originate outside the classroom. In the implementation of the print materials, some modification is normally made to accommodate significant characteristics of the students, the teacher, the school, and the community that are relevant to the learning process (Steely, 1980). When curriculum materials are down-loaded from a central main-frame computer or are produced on a local school computer, control over the format, sequence, and content is maintained by a responsible stake-holder, the classroom teacher. This action takes the teacher beyond the mere acceptance of prescribed material to a personal involvement in the development of the curriculum materials. Another related role of the teacher is the potential for communicating, back to the original author of the materials, the changes that have been effected, thus making possible greater participation by practitioners in the revision of the curriculum.

Implementation If a mainframe computer is used for file storage, the computer that is to download a file of computer-based materials must have a modem and a telephone line to the central computer. Both the terminal to the central computer and the local stand-alone computer require a printer capable of printing any required effects embedded in the materials, such as non-ASCII characters, subscripts, and graphics.

If teachers are to be able to modify the materials to reflect local concerns, the text editor of the file-management system on the central computer and the word processing program on the local computer must offer the ability to

- revise the textual contents by editing, searching, replacing, and moving contents and
- manipulate diagrams and graphics by moving or redrawing,

in addition to the normal file-handling operations of loading, saving, merging, and appending.

The operation of the system that presents the curriculum materials to the teacher is variable and dependent on the system from which the materials are received.

Illustration Although Merrills (1982) demonstrated the possibility of lodging junior high school science materials in the Curriculum Resources Information Bank within a central computer, implementation of that model has not proceeded sufficiently to describe the specific requirements for accessing, revising, and delivering these materials to students. The considerable potential is evident in the plan but requires implementation beyond the concept level to the level where reports can be made based on actual experiences of classroom users.

The most common source of modifiable computer-based materials in current use in the schools is in the files produced by a word processing program in a local computer. The operating knowledge required for customizing materials in either case is to work within any limitations of the system to handle files and to revise textual and graphic materials. In many cases, a group of teachers with a common curricular goal were using the same program so that interchange of files was possible. For example, a unit on Energy for junior high school students was being developed using Bank Street Writer because of the ubiquitous nature of the program and its ability to produce text files that were able to be used by other common word processing programs. Another group of chemistry teachers is using Gutenberg for the development, and mutual sharing, of textual materials and also for the accompanying testing materials available on disk for ease of revision and use by teacher clients.

The interviewed teachers noted that programming skill is not a requirement for this "desk-top publishing" but the teacher should recognize the technical limitations of the equipment to load and to print the available materials. For example, materials written using AppleWorks on an Apple IIe are inaccessible to standard Apple II+ microcomputers and some older printers, e.g., Centronics 739, can not print common Greek characters in text mode. Incompatibility of computer brands and models limits sharing of programs and files between teachers. Both district and provincial symposia have placed high priority on networking of microcomputers and mainframes for information sharing, including the production of materials (Redhead, 1986; Romaniuk, 1986).

Professional Development

Definition Of the wide range of possible uses for the computer for professional development, e.g., designing courseware, implementing one of the uses identified, etc., this study found ample grounds to suggest that the computer's ability to help a teacher access data banks for information and round-table conferences for discussions, as proposed in the questionnaire (Appendix A), could yield a bounty of opportunities for teachers.

Rationale The factors that limit the practicing teacher's ability to maintain contact with innovations and research in the profession are both time and financial resources. Using a computer for professional development has the potential for both reducing the total demand on these teacher resources and, simultaneously, for expanding the opportunity of the teacher to maintain contact with innovations and changes that are significant in the teacher's vocation.

The facility to communicate with data banks or bulletin boards will, initially, require both

- time to become familiar with the operation of the computer system in this use and to understand and evaluate the apparent benefits of this use and
- finances of acquiring the necessary modem and software.

The interviewed teachers identified that, in return for these investments, the teacher using a computer for this use will benefit by

- having to spend less time travelling to facilities such as Universities, Convention Centres, etc., where, traditionally, professional development activities have taken place,
- being able to contact these sources at times that are convenient to the teacher, and
- for local area contacts, or where toll charges are absorbed by sponsoring jurisdictions, no telephone communication or vehicle transportation costs are incurred.

Implementation If a teacher has access to a computer that is used for other professional purposes, e.g., word processing and marks maintenance, the addition of a modem and a software program, described in the background section of this chapter, represent the only hardware required for this use.

After the initial setting of the operating parameters of the modem and software, operation of the system consists of following the protocol for establishing contact with the host computer and selecting options from the menu for the intended activity. The details of the operation are typically described in the manual that accompanies the software or is available using a HELP function. Underwood (1981) found that, in lieu of documentation, a demonstration of the use is necessary. First-time users of the Conferencing System, COSY, at Guelph ON., also preferred personal support when learning the system (Harasim & Johnson, 1986).

The successful implementation of the conferencing facility is dependent on factors, identified by Harasim and Johnson (1986) and interviewed teachers, including

- the level of the teacher's expectation of the usefulness of the system,
- the number of new personal contacts made with other teachers with similar interests, and
- the yield of comments waiting for the teacher at each next signon.

Illustration Four forms in which a science teacher could engage in professional development using a computer are described below.

In one form, the teacher could observe and listen to a presentation of a topic to a large group using public broadcasting, e.g., ACCESS in Alberta or Knowledge Network in British Columbia, following which individuals could ask questions or provide feedback. In the manner similar to the way videocassette recorders have enabled "flex-time" viewing, the computer can make possible flexible post-lesson discussion and assignment submission.

Another possible form is a conference with peers or curriculum leaders of topics of mutual interest without prior formal presentation of material. In this form, a topic is defined, or "posted", on an electronic "bulletin board" by any person who then, as moderator, invites comments to be appended by other callers. The resulting discussion uses a "round-table" format wherein comments are available for perusal by interested teachers. Harasim and Johnson (1986) describe several facilities that offer this open format, including FORUM using the Michigan Terminal System, M.T.S., available to staff and students at the University of Alberta. Several conferences, each on their own topic, may be run concurrently and callers are able to participate in any topics of interest.

A third form of using the computer for professional development could be for assisting the teacher who is searching for reference material on a topic and, as such, is one of the information retrieval applications described later. Library catalogues are converting from card systems to on-line computer data banks resulting in benefits of thoroughness of search and less time consumed by the library user. These same benefits are available for teachers who are using the Educational Resources Information Clearinghouse, E.R.I.C., list of recently published material using a computer search instead of scanning the entries of a bound paper copy.

A fourth example of the use of a computer for professional development is found in YORK ON-LINE SERVICE, sponsored jointly by York University and IBM Canada, wherein teachers currently may access, using a toll-free number through iNet 2000 of Telecom Canada, data bases related to microcomputer educational software and special education, an electronic bulletin board, and a facility to allow users to enter their own evaluations of educational software (Owston, 1986). Generous documentation and HELP facilities are provided, including samples of the dialog expected while accessing the service.

Communication between Teachers and/or Schools

Definition There are two uses of computers possible under the broad topic of institutional coordination: a) communication between teachers in schools using a central computer and b) communication by schools to a central computer for processing student records. This study focuses on the former use by science teachers.

Rationale This "mail box" facility is an alternative to surface inter-school mail delivery by either district vehicle or by Canada Post. As such, it has the potential to reduce transit time between originator and addressee. A further advantage is realized by the itinerant teacher who may "pick up the mail" from a terminal at any location in the system in a manner similar to telephone pagers used by staff with responsibilities at multiple job sites. A related advantage is the speed of addressing and delivering mail to an employee who may have moved to another school.

A disadvantage to the electronic mail system is one that carries over from the traditional method where the addressee may neglect to "clean out the mail box". This is more probable for staff who have not incorporated the computer into their daily routine or who would rarely receive mail using the computer. For teachers who would infrequently use a computer to check in to the message facility, a mechanism would need to be contrived by the host computer to allow each school to sweep the mail boxes and to provide a notice of message waiting for the teachers.

Implementation The physical requirements for this system are a central computer with sufficient memory to accommodate the volume of material transferred. The terminals in the school could range from the simple, but slow, DECwriter printer/terminals, up through the school's computers with their modems, to the facsimile machine, FAX, for transmission of virtual copies of the original document (FAX, 1987).

For all of these types of electronic mail, the operating knowledge required is restricted to the protocol necessary for contacting the mail facility and is part of the general knowledge required for inter-computer communication. Keyboarding skill is an asset when text material is to be sent.

Illustration There are three sources for the material to be sent by electronic mail.

- The simplest form is for the message to be typed onto a terminal, addressed, and sent using a system similar to the $MESSAGE facility on the M.T.S. computer at the University of Alberta.
- Another source of material to be sent could be a text file that had already been created, perhaps by a word processing program, and which could then be sent as a prepared package to the addressee. Also included in this category would be information kept at the school in data management programs, e.g., science staff may forward orders to district personnel for science equipment or for film or print materials from resource centres.
- A third possible source of material are visual images that cannot be sent as printed text. Because of the lesser

quantity of these non-textual materials, the large amount of electronic data required to form an exact copy of the document, and the current high cost of facsimile machines, this use will probably be restricted to specialized applications in the school, such as diagrams, graphs, historical documents, music scores, etc.

Instructional Resources Applications

Definition This use was formerly labelled "library applications". It has now been broadened to include accessing all the instructional resources, whether references, printed materials, supplies, or equipment, used by teachers in science. The definition, as presented in the questionnaire (Appendix A), has also been restricted; the use of the computer by a librarian for administration of the resources, e.g., ordering, circulation, overdue lists, etc., is not normally an activity of science teachers and, thus, is not included in this study.

Rationale The resources available to a science teacher require some form of organization if retrieval for use at intervals during the school year is to be efficient. For example, the interviewed teachers longed for a means of organizing their periodicals so that course-related articles could be identified, by the teacher and the student, for retrieval and use at appropriate points in the course. Except for those trivial items that are limited in number or are not subject to change and can be stored in folders or on shelves, a computerized information retrieval system can increase the teacher's productivity while planning and conducting study in the units of a course.

The maximum benefit of using a data management system on a computer is derived when a large amount of information is stored that needs to be retrieved and reported either frequently or in a variety of formats. The currency used to measure the extent of the benefit is the net time saved.

Implementation No special characteristics of the computer were identified. The interviewed teachers identified a fast printer, i.e., dot matrix, as a necessity for presenting the results of most searches. The number of disk drives required for the implementation should be noted in the operating manual. A monochromatic monitor offers compact, readable screen presentation of the information.

A good information retrieval system will be menu-driven and have screen prompts and "HELP" pages. A knowledge of file handling is desirable but no programming skills are needed.

A general data management system that is flexible enough to be used for storage of a variety of information will distribute the cost over, and increase the productivity for, several applications. The program should be easily operated by a variety of users. Characteristics of a data management system normally include the ability to

- edit records by adding, deleting, or correcting information,
- display records on a screen or to a printer,
- save and retrieve records using a minimum number of steps, and
- format the retrieved information in various patterns for specific purposes.

The benefit of the last feature is apparent, for example, when a chemical inventory file, such as was being developed by an interviewed teacher, is to be printed with the records arranged according to various fields of data;

- by name of chemical for general surveys of quantity of stock,
- by course and level for preparation of supplies for a specific laboratory exercise,
- by class of chemical for section-by-section checking of inventory of incompatible chemicals, or
- by name of supply house for re-order of stock.

Illustration The most common form of data-based information retrieval program found in the schools of the interviewed teachers was on a disk in a microcomputer. For this source of program, such as the dual PFS:FILE and PFS:REPORT, the teacher determines the format and the contents of the records.

Because of the time needed to initially enter the information into the files, careful planning of the format of the files, based on present requirements and allowing reserve for future needs, will result in an effective and flexible system. For example, some of the interviewed teachers created blank fields to hold spaces for information that might later be found to be necessary.

The resource materials that are significant to science instruction, some of which were catalogued by the interviewed teachers, include

- print media as textbooks, library references, periodicals, or newspaper clippings, or
- encoded or miniaturized media as videodiscs or videotapes; film strips, film loops, film slides, or transparencies; or audio recordings,
- curriculum banks of printed materials for teachers or students,
- laboratory-related equipment or chemicals, or
- plans for curriculum topics to develop,

Instead of using a floppy disk computer program, the operating program and its stored information may reside in a remote mainframe computer, for example, the Educational Resources Information Clearinghouse (E.R.I.C.) data base or the electronic library catalogue available on the University of Alberta's computer. In this case, the teacher will work within the confines of both content and format predetermined by the program designers. In exchange for these restrictions, the sponsoring agencies normally offer orientation material or help for the user.

Instructional Management

Definition As described in the questionnaire (Appendix A), this use of computers, relying on educational objectives-dependent procedures, materials, and measuring instruments, uses a cycle of criterion-based test scoring, diagnosis, prescription, and reporting to provide the means by which the teacher manages the educational enterprise so as to offer each learner an optimum set of educational experiences.

Rationale Administrative and clerical tasks that precede and follow instruction and learning are activities where substantial assistance can be rendered by the computer in schools in which students learn a subject at their own level and rate. With its capacity for storage and selective recall of characteristics of the subject and the student, the computer was recognized by the interviewed teachers as playing an important part in the daily decisions relating to the screening and evaluation of students and the sequencing of instructional modules.

The initial teacher activity is the evaluation of assessments on students who are entering a program. Whether these are ability tests administered by a special education team or are achievement tests administered by a teacher or a computer, the readiness of the student to enter at a level that is appropriate to their ability and background is normally established.

The curriculum must also be well defined so that the computer can issue unambiguous directions for activities that will result in student achievement in the course. Thus, the goals and objectives must be detailed and be sequentially arranged.

For each of the subsections of the content area, an appropriate selection of learning activities must be identified and experienced and an adequate number of test items must be constructed and administered to measure the student's progress through the module. Lastly, a mechanism must be devised to record the results of tests and to implement appropriate action based on these test results.

Although the teacher plays a substantial part as a course organizer, the interviewed teachers found that his/her roles when the Computer Managed Instruction is underway become that of a facilitator to the students who are involved in the process of learning and a tutor to those students who are experiencing difficulty with learning the content of the course.

An interviewed teacher noted that a supplementary, administrative benefit from computerizing the management of the learning in the classroom is the ability of the system to aid in the preparation of reports that document the programs and progress of special education students in the school jurisdiction.

Implementation A variety of software programs, either as stand-alone programs or as adjuncts to C.A.I. programs, are offered by manufacturers or independent publishers for most computers. The most significant criteria for evaluating the software is the flexibility of the program to accept input from local teachers and school system personnel regarding

- goals and objectives for the course,
- parameters for permitting passage of students between modules of the course,
- routing of students through the activities in the course, and
- test items and procedures for evaluating student's progress.

The programs that are designed to process the data base implicit in the above management are invariably menu-driven. According to the interviewed teachers, neither programming knowledge nor general technical knowledge, concerning equipment or program troubleshooting, is required unless the implementation is in its developmental stage.

The amount of student and course information accessed by a computer managed learning program generally requires either a large RAM memory or frequent recourse to the disk storage device. A mix of hard copy terminals and video display terminals offers alternate forms of output for various student and teacher activities. Disk access and printer speed need to be rapid to reduce waiting time for students receiving assignments or tests.

The interviewed teachers identified a large overhead of teacher and staff time required for

- defining the behavioural objectives for the students' progress,
- mapping the routes through the course objectives,
- assembling a variety of effective learning activities for students with differing learning styles,
- orienting students to receiving instructions at a computer terminal, and
- constructing sufficient test questions to assure production of several parallel tests for achievement.

Thus, the introduction of a computer to management of instruction is most probably implemented in a school across a well-defined course with further expansion progressing on the basis of experiences gained with the initial limited implementation. During this shake-down period, teachers may prefer to phase in their reliance on the computer system by using the computer-generated tests as review exercises, retaining previously prepared "proven" tests for evaluation.

Illustration The computer can be integrated into the management of the students' course of studies at two levels:

- the computer can aid the teacher in planning an Individualized Education Program (I.E.P.) using the first two aspects of instructional management, where the ability of the student is mapped onto the course objectives to identify the starting and stopping points for the student's unique program or
- the computer can use all three aspects of instructional management to guide the student from activity to activity in a course so that the course objectives are attained.

A refinement of this second level is the coupling of this computer managed learning with instruction received directly from the computer (Computer Assisted Instruction, C.A.I.). Forms of this instruction are described later in Phase II of computer uses in education.

Phase II: The Teaching/Learning Act

Problem-Solving

Definition In most applications in Phase II of the teaching/learning cycle, the computer functions as the dispenser of the information and the program determines the process by which this information is transferred to the learner. In problem-solving applications, however, the control over the process and the product of the computer operation is retained by the student. In this use, the student, using the computer, constructs a model of a real-world situation or system and then notes the degree of conformity to or discrepancy with the real situation. This "open-ended" use of the computer is not limited by the pre-planned structure present in most other programs in this phase of teaching/learning.

Rationale The basic processes of problem-solving - define the problem and implement the solution - are subdivided in Polya's (1973) four steps for problem solving (understand the problem, make a plan, carry out the plan, and look back). When used in a computer environment, these processes are further refined by Moursund (1983) and Wright (1985) as

- understand the problem, including
  - what is known,
  - what are the allowed types of operation, and
  - what is wanted,
- select or develop a solution procedure, including
  - step-wise refinement of the problem into identifiable "primitives", or basic procedures,
- write the program, including
  - identify the flow of the algorithm using natural language, block diagrams, or flowcharting,
  - select the programming language, and
  - write the program code,
- enter the program and data, if required,
- test the program, including,

  - debug the program,
  - verify the robustness of the program, and
  - validate the product of the program's operation, and
- document the program, including the
  - program's architecture for project initiator,
  - program listing and comments for possible revision, and
  - user's guides describing program operation, limitations of applications, data entry, and expected output.

Evaluation of a student's program could employ criteria similar to that used for a conventional laboratory report, including

- accuracy of the calculations, if any are performed,
- quality of the communication with the reader, and
- evidence of activity in the problem-solving steps.

Implementation Because of the amount of time required to enter and debug the program, students will need access to a computer at home or in the school. To enable practical use by the teacher and/or other students, the program should be operable on available computers.

The students may write the program in any language compatible with the classroom computer. The students usually prefer to write in BASIC. The rate-determining step in subsequent use in a class is usually data-input by the ultimate user of the program and not because of the speed of processing by the program.

The teacher who intends assigning program-development to students as a problem-solving activity will need to

- have a sound knowledge of the science content to be described,
- have clearly defined the assignment and specified the anticipated outcome of the activity,
- have a computer background or have access to assistance for programming, and
- understand the size and complexity of the task in relation to the ability and interest of the student to bring the project to a successful end.

The teacher-sponsor of this program-writing activity, in addition to providing the initiative of suggesting possible subject content as a focus, will need to provide guidance and support to the student during the construction of the program.

Illustration In one possible application of computers to a student's problem-solving, a student may write a program instead of submitting a laboratory report. The program, when completed, could be used by other students in a later semester to calculate the final value for the same laboratory exercise (as described later in this Phase as Experimental Analysis). This subsequent use would confirm the students' calculations, thus aiding the student in verifying their calculations and allowing faster marking by the teacher who could focus on qualitative aspects of the laboratory report.

The purpose of the program-writing assignment would, in addition to providing an opportunity for application of knowledge from another curriculum area and the development of problem-solving skills by the student, result in a product of value to other students and enable contribution by students to the artifacts of the classroom.

In another application, the ability of the computer to perform rapid calculations could be used to calculate a value in thermodynamics where the use of a calculator is a highly repetitive, mechanical process. For example, the temperature of a cooling body could be predicted by applying Newton's Law of Cooling (Kelman, 1983). After measuring the temperature of a cooling object at intervals, a trend would be observed, graphed, and possible mathematical models of the behaviour identified and tested and a prediction made. At this point, students may elect to write a computer program that uses a short-period iteration method of approximating the cooling curve.

The purpose of this laboratory-derived exercise would be to give the students practice at

- making precise laboratory measurements,
- identifying and analyzing trends,

- predicting relationships and values, and
- giving students experience with the dynamic nature of thermochemistry.

The computer would be used to amplify the students' performance in the second and third activities by refining processes that the student would conventionally use.

Simulations

Definition In this use, the student is exploring a system under study, as presented in a computer simulation, by adjusting the parameters available in the program and noting the effect on the system.

Rationale A central question for a teacher who is considering using a simulation is "Under what conditions is controlling a model more educationally sound than is controlling the referred system? When is a simulation better than the real thing?"

Although the interviewed teachers and most of the references generally preferred the laboratory experience on which the model (and simulation) is based, the specific simulations fell into four categories, i.e., those that tested models that represented phenomena that, within the classroom/laboratory setting, were

- impossible or inconsistent with good practice,
- difficult or required unusual time or skills,
- easily reproducible, or

- so complex that the most essential variables were obsured. The rationale would probably be different for using a simulation from each of these categories.

Rivers and Vockell (1987) found that those students whose discovery of concepts in biology was guided by descriptions of strategies to use as they solved the problems presented in the simulation achieved results on standard posttests (measuring specific problem-solving skills directly related to each unit) that were equal to or significantly better than other groups that were not guided or that did not use computer simulations. Clearly, the traditional support of students is part of their effective learning using this new technology.

Implementation The program and hardware must incorporate good design characteristics to achieve a "transparency" between the student and the model so that the simulation achieves both the teacher's curriculum objectives and also the student's motivational objective of realism. High resolution graphics increase this realism. In addition to the usual requirements for good presentation (speed of operation, menu-driven, "HELP" screen, etc.,) the program should provide some data capture for the teacher so that a record of the performance of the students is available for assessment of the student-simulation interaction and so that remediation for the student is indicated.

The teacher who uses a simulation is a facilitator, giving background information, introducing the program, monitoring and coaching the students during the activity, and leading a post-simulation debriefing to ensure that the teacher's objectives for using the simulation have been met (Wright and Forcier, 1985).

Illustration One simulation, HABER-TECH, clearly from the first category because of capital costs and operating hazards, allows students to manage their "own ammonia plant for fun and profit!" The objective of the simulation is to produce a steady-state synthesis of ammonia from its elements. This simulation would probably be included as one of the activities in a unit on equilibrium and would follow laboratory exercises and demonstrations of the application of Collision Theory and the predictions based on Le Chatelier's Principle to systems in equilibrium. Pre-simulation instruction, specific to this industrial setting, would include the distinction between equilibrium and steady-state conditions and also a tutorial, available on the disk, on the plant design and the manipulation of operating parameters from the "control room."

A simulation from the third (reproducible) category might be an acid-base titration. In this category, the simulation might precede, instead of replace, the laboratory exercise. In this case, the objectives could be to review equipment-handling and data-gathering before going into the laboratory. Although a teacher-led demonstration could achieve these same objectives, some circumstances, e.g., individualized progress, may favour this computerized pre-laboratory orientation instead of the demonstration set-up. This check-in could also include a sequence of selecting and ordering procedures, reading instruments, and calculating values to screen laboratory entrants.

In a third simulation, TRIBBLES, where the student practices scientific skills including data-gathering and hypothesis-generation in a "microworld", designed so that all earth-bound students with varying background knowledge are placed on an equal footing, the teacher takes a less prescriptive position regarding exposition of content and, instead, encourages student growth through exploration and inquiry.

Tutorial

Definition In the instructional dialogue between the student and the computer, the student responds to questions posed by the program. The computer evaluates the student's responses and, on that basis, branches to alternate sequences for either remedial or new material.

Rationale As a tutor, the computer/program system is designed to emulate the teacher in a one-to-one session with a student. This session may be computer-led as a didactic tutorial or student-directed as an inquiry (Digital, 1983).

Most tutorial programs are of the former pattern wherein the program delivers the instruction and periodically asks problems to verify the progress of the learner. Based on the correctness of these replies, the program will either branch to remedial instructions and problems following incorrect responses to the average problems or will branch to advanced questions on the same concept following superior responses to the average problems. Thus, the computer-as-substitute-for-human- tutor is expected to offer a measure of responsiveness to differing levels of students.

Tutorials tend to be effective when used for concept building when students may be channelled by limited response options. However, the limitation of its usefulness is reached when the student is ready for expansive and creative experiences that explore the complexities of the subject matter (Coburn, 1985). Tutorials then are effective as part of a program of studies. The teacher should recognize the

- restriction of multiple choice answers to the responses anticipated by the author,
- the limitations for transfer of objective answers (multiple choice, true/false) to real life situations, and
- the task of analysis of short phrase answers on the answer-judging capabilities of the programming or authoring language.

A less restrictive pattern of tutor/learner interaction is found in the second pattern where the student, as an inquirer, poses questions to the data-based computer that responds to the information requests. Although this format poses demands on the program for question analysis and thoroughness of the data base, higher level processes, such as pattern recognition, problem identification, and question generation, are developed by the student.

Implementation Operating knowledge for a teacher whose students use a tutorial must, then, include the entering of values for the multitude of parameters, e.g., number of clues to offer after incorrect responses, number of successive questions correct for promotion to advanced problems, etc., that control the program's stepping laterally between achievement streams and longitudinally through the sub-concepts. The above noted requirements for individualizing instruction have implications for the memory/disk storage specifications of the hosting computer. If the program is operated from a central computer, knowledge of the protocol of accessing is also required by the teacher. The student will need to know how the courseware relates to other course activities and content, how to access the HELP pages, and how to activate options that are available for student-control of movement within the program.

At all times, the opportunity for contact with a human teacher with inherently non-programmable features is present.

The teacher should recognize that the essential criteria for selecting and using tutorial programs is that the student should be able to

- use the material easily,
- accomplish the objectives specified by the teacher and the program, and
- enjoy learning with the material, and

that the program helps resolve an instructional problem which was previously unreachable or inadequately resolved through other means (Roblyer, 1983).

Illustration A possible application of the inquiry pattern could be the use of a program that would allow a student to ask a computer for the results of chemical tests on an unknown chemical. Based on these results, the student could consider and ask for other specific test results. From the composite results of these "tests", the student could predict the class and/or name of the chemical before doing a "wet" lab test of an unknown substance in a qualitative analysis experiment. The benefit of this pre-laboratory check is that the student would show recognition of the significance of the identifying tests at nodes of the tree branches and be able to use the laboratory time more efficiently.

Drill and Practice

Definition The purpose of drill and practice programs, as defined in the questionnaire to the science teachers, was the maintenance of basic skills and concepts.

Rationale Recognizing that drill and practice exercises can be a drudgery because of their nature of rehearsing old material, practicing teachers frequently employ various techniques, such as games, puzzles, "pop" quizzes, etc., to liven up this routine. On this count also, the computer, because of its capability for animation, color, and variety of pace, level, and display format, has the potential to aid the teacher and students in their tasks.

Implementation Displaying the situations and questions will require either a bank of problems or a question-generating template/algorithm. The practice exercises will need to be indexed by sequence in a conceptual hierarchy and difficulty level if a range of users are to be accommodated.

If using a multiple choice format, a matched set of anticipated alternate answers are needed, or if the program uses a short phrase response format, response-analysis is needed. Computer programming routines that judge free responses are currently under development and usually are restricted to authoring languages, such as SuperPILOT.

Programs can be written with performance characteristics ranging from "electronic flash cards" to integrated components of a computer managed learning system. Time will be needed by the teacher for familiarization with the program, a process often not adequately treated in the users' manual. Requirements by a class may be a portion of the students rotating through a set of computers during the period or a partial period, complete class equivalent. A teacher considering this use of computers should know what role drill and practice is projected to have in the curriculum program of the student, and what computer, software, and time resources are available to support this use.

The ability of a student to complete complex tasks usually requires mastery of primary, low-level skills. A teacher will then, as students progress in their skill development, make provision for practice of component low-level skills. Whether requiring drill, where exceptions to rules are rehearsed, or practice, where rules are applied, some portion of the class time is normally set aside for this purpose. During these practice periods, the teacher may review the material to be practiced, assign and check specimen problems, re-teach apparent problem areas, and assign and gather for marking some remaining problems, the evaluation of the answers to which will influence future lessons. The computer has the capability, through its performance in the above activities according to the various uses described elsewhere in this study, to allow much of the teacher's time to be released for activities requiring the teacher's personal intervention.

Illustration A drill-and-practice program must meet the following basic criteria for acceptance by students and teachers:

- easy to use,
- adaptable to a variety of user levels,
- interesting to the learner, and
- educationally valid (Vojack, 1980).

The chemistry and physics programs available on the PLATO system were frequently cited by the science teachers as exemplary for drill and practice applications.

Another application, from some of the interviewed teachers' elementary and junior high school mathematics programs, is the thirteen disk Milliken Math Sequences practice program where the students receive twice weekly fifteen minute practice sessions on maintenance on basic mathematics skills. The teacher structures the sessions by prescribing parameters for the program's operation, including setting the level for mastery passing from a unit, the minimum number of exercises to be completed within each unit, etc.

Instructional Gaming

Definition The essence of gaming is the element of competition, either with the computer or with other students, that provides motivation for a lesson. The determination of a "winner" is the goal set by the program. In the questionnaire (Appendix A), this use was labelled as "Gaming" but, at this stage in the study, the modifier "Instructional" is added to emphasize the classroom, rather than arcade, possibilities of this use of computers.

Rationale The characteristics of gaming - enjoyable, involving, and challenging - are ideally present in all effective use of computers in Phase II of the learning cycle. Of the various uses in this Phase, gaming is most suited for developing group dynamic skills of cooperative effort, shared responsibility, and communication (Riedesel & Clements, 1985). What makes gaming unique as a mode of learning is, however, the competition either between groups of students or between a student and a computer using a defined set of rules resulting, usually, in the declaration of a winner at the end of the contest (Wright and Forcier, 1985).

Implementation The early distinction that the teacher needs to make is between games that are primarily recreational and those that develop or reinforce instructional objectives that are embedded within social, psychological, and cultural values (Coburn, 1985). Thus, the popular HANGMAN would be rejected if a teacher accepts the learning theory that rewards successes instead of punishing failures (Sparks, 1982), as would many adventure games that, through vicarious role-playing and superb eye-hand coordination, promote the use of direct conflict and aggression to achieve survival.

Wright and Forcier (1985) assign to the teacher the tasks of

- setting limits on the game,
- directing the process, and
- monitoring the result.

Thus, at an early stage preceding introducing a game into the curriculum activities, the knowledge, skills, or abilities that are to be achieved should be specified.

After a program that meets these criteria is identified, the teacher should preview the game and identify features relating to the actual implementation, including

- ease of use and quality of directions,
- interesting format and pace of events,
- the appropriateness of the computer to host the described activity.

The validity of assumptions that are part of the algorithm should be identified to determine the probability of transfer learning to real life situations (Coburn, 1985).

User-control features should include the options to select

- either competition between a student and the computer or between individuals or teams of students using the computer and
- the set of identities that are to be used as the objects to be manipulated or won in the game.

Lastly, the teacher needs to plan and include lesson components to merge the game with other classroom activities, such as

- ensuring that prerequisite material have been introduced,
- enabling practice, without a computer, of skills present in the game, and
- orienting the students as a whole class to the operating rules of the game.

Illustration A possible application for a chemistry class could be to introduce as a game, but containing a drill and practice core, MASS-OUT wherein, from an agreed set of elements and their charges, ionic compounds and their molar masses are proposed that have the greatest molar mass. Points equal to the compound's molar mass would be, if calculated correctly, awarded to each contestant. As the ionic species are used and removed from play, the possible combinations would be restricted thus bringing the game to a natural and rapid closure. This game would recognize excellence in

- recognizing characteristics of chemical elements significant to the goal of the game,
- gathering relevant information, viz., combining capacity and atomic mass,
- formulating alternate playing strategies and evaluating choices using these characteristics to select large molar mass compounds,
- writing correct formulas for ionic compounds, and
- correctly calculating molar masses of the proposed ionic compounds.

Post-game discussion led by the teacher should ensure that the techniques for increasing the chance of winning are shared with all students.

This game would use the computer's capability for rapid calculation of values using information retrieved from data statements. If the students are intrinsically motivated by the competition on the chemical content, neither screen graphics nor audio feedback would be required.

Electronic Chalkboard

Definition The computer may also be used to present textual or graphic material to, or to compute the values of functions for, a class of students to enrich, illustrate, amplify, elaborate, or reinforce the teacher's instruction.

Rationale According to the teachers in the study, the electronic chalkboard as an adjunct for delivery of course material appears to be recommended when a number of conditions are present, i.e., where

- learning the concept is enhanced by movement or animation in the display, such as the replotting of line graphs from revised data or the grouping of related specimens in an exploration using dichotomous keys or
- the interaction between variables of a phenomena is studied to encourage numerical insight into the mathematical relationship (Thompson, 1982).

This electronic equivalent of the overhead projector also offers color coding, by block or by figures, of key related concepts. The quality of the screen layout, including factors affecting legibility such as size of characters, is also equally significant for both computer- and overhead-projected displays. Electronic Chalkboard programs, such as the Image Printer from C & C Software, provide a range of font styles and sizes.

This use of a computer also creates other kinds of overhead, including

- increased hardware and associated budgetary concerns, especially if multiple large-projection screens are daisy-chained for increased visibility in a wide room.
- a five-fold increase in teacher time required for

preparation of textual display material for computer media compared to paper notes (Clark, 1983). This requirement would be increased if graphics are to be included or if a teacher provides handouts to minimize note-taking by students, an activity exacerbated by the potential for rapid page-turning by the teacher.

Implementation A teacher who is considering bringing this computer-controlled teaching aid into the classroom should know that it appears feasible where, in addition to the conditions described above,

- facilities and release time are provided for preparation of materials by individuals teachers or teams of professionals,
- a large group of users exists to amortize developments costs, e.g., the $2000 fee for producing the initial copy of a videodisc, later copies of which cost $20 each (Bosco, 1984), and
- the teacher will use the prepared material in particular and the computer/program system in general to justify the initial orientation period and so that the routine of operating the system is minimized and attention is returned to the students and their learning activity.

Illustration One teacher in the study had used an interactive videodisc in Biology within his principle motivation of providing a versatile alternate media to films. A sophisticated computer program could also provide this feature but the quality of the graphics using the videodisc was superior.

In another application, a interviewed science teacher uses a spread sheet calculation of various possible relationships, e.g., quotient, difference, log ratio, sine ratio, etc., of two variables, viz., the angles of incident and refracted rays in physics, to enable a search by students for the generalized law that best describes the behaviour of light from several observations at varying angles recorded in a specific experiment.

Laboratory Instrumentation

Definition Science teachers have had experience for several years with instrumentation of observations in the laboratory, including photogate timers in physics, electronic balances in chemistry, and pH meters in biology. The acquisition, storage, and processing of analog or digital data directly from experimental apparatus by a computer and the control of attached devices by analog or digital signals, however, has opened fields of technical knowledge and pedagogical opportunity not yet explored in an educational context by the interviewed teachers.

Rationale The pedagogical opportunity opened by this data-gathering activity was viewed by the interviewed teachers in a manner similar to simulation; both are regarded as modifying or encroaching on the traditional laboratory experiences of students which is one of the key characteristics of science study. A teacher needs to identify, amongst the measurable quantities of

- conductivity, displacement, electrode potential, force, humidity, luminosity, mass, pH, pressure, sound, temperature, time, velocity, volume, etc.,

where the use of the computer is warranted. Accepting the primacy of "hands-on" experience as letting the students do what they can do and letting computers do the rest, applications can be considered that

- extend the range of measured values beyond the limits normally available to students (Thompson, 1982) or
- assign the computer the function of tireless accumulator of data, allowing students to focus on the phenomena or science principle under study (Tinker, 1981).

Although the computer aids the collection of data in an experiment, it also can be perceived to come between the students and the phenomena being studied. The point of optimal balance between manual and computer-aided experimental work is one that each practicing teacher must find.

Implementation The technical knowledge component appears in the form of the binary and Boolean basics of computer logic, the electronics of data-processing within the computer, and the operating characteristics of electrical circuits. A perception of the role of the game or user ports or an interface card in permitting attachment of devices, similar to the way the keyboard is electronically attached to the main computer circuits, is required. The teacher must also recognize the limitations imposed on the voltage and current of circuits attached to the computer.

Computers differ in the ease with which they facilitate measurement of these observed values. Up to four phenomena that can be measured using the BASIC command, PDL(n), as analogous variables, such as those indicated above, can be inexpensively measured through the game port of an Apple II computer using 150 kohm low-torque potentiometers, to the shaft of which is attached a mechanical arm, the position of which is related to the phenomena under study, e.g., a weather vane indicating wind direction (adapted from Horst and Dowden, 1986). Although the measured resistance is proportional to the observed phenomena, the program must provide for the calibration of the system. The Apple II can also monitor three switch inputs which can be activated by proximity switches such as magnetic reed switches. The PET computer has eight lines at its user port through which digital signals may be passed.

The devices that are attached may be built from components following a design based on electronic and electrical theory or may be purchased from science supply houses (such as PASCO equipment available through Merlan Scientific) as plug-in appliances requiring minimal technical background (PASCO, 1987). The program that controls the flow of signals into and out of the interface ports may be written in machine code, for fast operation, or in a higher level computer language, e.g., BASIC, for easy revision (Thompson, 1982).

Illustration In Brasell's (1987) description of the benefits to students of "real-time" graphing of observed kinematic phenomena over a three-day cycle of pretest, treatment, and posttest, she notes the need for

- presenting only distance or velocity graphs on the screen (and not acceleration graphs) to reduce the amount of data presented and thus to minimize confusion,
- familiarization with the equipment and basic graph patterns and prediction and reproduction activities using distance and velocity graphs for a complex event, and
- a sufficiently long experimental period for students to confirm their results and to confront conflicts between their expectations and reality.

Another possible application of the computer for data collection where the limits of experimentation could be extended beyond that which is reasonable for student work is the monitoring of weather conditions, such as hours of daylight, wind velocity, rate of precipitation, barometric pressure, etc., for twenty four hours each day over an interval of several days. The resulting data is then retrieved for conventional analysis by the class or analysis assisted by the computer. Use of the computer for lengthy periods, however, would need to be integrated with demands by other staff.

Experimental Analysis

Definition This use of computers was originally classified in the questionnaire (Appendix A) as post-lab "number-crunching" under "Simulations". Creation of this new use was initiated by response comments from participating teachers and based on reflection on the lack of overlap between this analysis and the primary modelling.

Rationale The rapid calculation and display by a computer of experimentally derived values provides a useful aid for both the student and a teacher. The student benefits from this data reduction by knowing,

- before dismantling the laboratory equipment, that the measured values are acceptable (Thompson, 1982) and
- after doing a manual calculation, that all steps in the calculation sequence are probably correct if the final answer of the student and the computer agree.

The teacher also can benefit from this use of a computer,

- indirectly, by knowing, if the results of the calculation check by the student were acceptable, that the teacher can focus, during evaluation, on the qualitative aspects of the experiment reports and
- directly, by entering experimental values from student reports to confirm the student's derived values.

The teacher who introduces this use of computers will note that students will generally accept the trade-off of time to become oriented to the use of the program in exchange for the validation of their calculations. The usual pre-lab orientation the day before the experiment is an ideal time to include a printed sample screen display and a walk-through with simulated data with the effect that the time for data entry during the laboratory period will be correspondingly reduced. Two computer and printers can accommodate the students during the last half of the laboratory period.

If a teacher uses the program for checking intermediate and final calculations, some provision should be available for the teacher to bypass any student errors at intermediate stages so that later calculations can be checked based on error-free calculations.

Implementation In addition to the question of who enters the students' measured values and who benefits from the calculation, another point to be considered by a teacher is regarding the amount of information to be produced by the program. Most of the interviewed teachers preferred giving only the final calculated value to students but displaying intermediate and final values to teachers, consistent with the objectives for the program's use.

An alternate form of experimental analysis is the graphic representation of measured values. In all forms of the displays that confirm the student's analysis of experimental observations, the interviewed teachers required previous or concurrent presentation or confirmation of the student's ability to perform tasks equivalent to those completed by the computer.

The program should be simple in both its instructions to the user and input of experimental data with the option available to have the answer(s) printed on paper in addition to being displayed on the screen. Although printing would require more time per student, attaching the paper copy to the experimental report would document the calculated value.

Illustration Most programs are simple, written in BASIC, and are a suitable assignment for a beginning computer science student or as a problem-solving project (previously noted) by a capable student. Alternatively, spreadsheet programs, such as VISICALC, with their flexible format are eminently suited for this purpose, although slightly more orientation for initial users would be required. Some textbook publishers are marketing data-checking software for their integrated science programs (Merrill Publishing, 1985).

Phase III: The Testing and Evaluation

Test Production

Definition The production of tests for evaluation of students' progress may be achieved by either a) the storage and retrieval of single test items or complete tests or b) the generation of tests using a pattern.

Rationale A teacher considering using computers for this purpose should know that a wide variety of options exist within the schools and include the decisions to use tests that

- are prepared and printed by the teacher or accessed by the student directly from a computer (terminal),
- are created from banks of questions filed according to content objectives or created and stored as complete, integral tests,
- incorporate symbols and diagrams within the test or as an addendum to the test,
- are produced from intact test items or by automated insertion of random values into a question pattern, and

- include other more familiar criteria, such as including questions to be objectively or subjectively evaluated.

This last option is currently not possible with accuracy because of the current state of the development of answer-checking routines involving word recognition and syntax analysis. Each of the other options suggested introduces its own nature of specialized knowledge and are frequently selected in special areas of the school setting.

Inclusion of symbols and diagrams by science teachers has caused difficulties for, and creative solutions by, teachers including

- sketches using non-alphabetic, non-numeric characters such as, ! _ = . / \, etc.,
- diagrams hand-drawn or pasted on to the test before duplication, and
- referral of students to a specific diagram from a standard set appended to the test.

Large-memory microcomputers and word processing programs with an integrated graphics-drawing component, such as MacDraw, has made these non-electronic cut-and-paste techniques archaic.

Implementation Tests delivered directly to the student are, by reason of the number of terminals required, generally restricted to student-centred schools offering individual student progress programs. The teacher in this milieu will know how to control the flow of questions from a bank of questions to the student by setting values of parameters, including the number of questions in the test, the mean difficulty level, the concepts to be tested, number of questions per concept, etc. Within these restrictions, a large test item bank can support the production of a variety of unique, parallel tests for initial tests, re-tests, or for other classmates. The test may be printed on paper or on the screen depending on the type of terminal provided.

The storage of test questions as separate items instead of complete tests was preferred by the science teachers as giving them more flexibility in the produced test. The individual test items usually contain descriptors, such as a serial number, degree of difficulty index, discrimination index, and a record of past usage and the question itself. A test is usually tailored to specifications set by the teacher and constructed by reference to these descriptions.

A test stored as a text file in a word processor was found to be most amenable to revision of separate items or of the length of the complete test.

A skill frequently identified by the interviewed teachers as prerequisite for accomplished test production was the ability to type. Knowledge implicit in this use of computers is an understanding of the methods of accessing and managing files and of operating the program that achieves these ends.

Illustration The test that is prepared by a teacher and printed by a computer is likely to be the norm for most teacher-centred classrooms and is an amplification of the long-used typewriter and spirit master model. The teachers in the study cited the ease of storage, retrieval, and revision of tests or items, using any of the common word processing or data-based management programs, as reasons for using the computer. The potential for revision on the basis of

- post-exam feedback from the students or item analysis or
- changing emphasis in the curriculum or class interests is a special benefit of using computer-assisted test production.

The test items referred to above have been described as separate entities. Another type of test question, usually used by the interviewed teachers for a whole test, consists of questions which have a general format into which randomly generated values are inserted. Several questions, each generated according to their own template, are assembled into a test which, although using unique values, follows the same pattern for all students. These individualized tests, although cranked out by a program that produces one-size-fits-all questions, encourages individual student performance during tests. Marking of the test is made easier by the inclusion of a computer-calculated answer key for each test.

Test Scoring

Definition The grading of answers to tests may require checking from a limited set of responses (e.g., multiple choice, true/false, and matching) or analysis of open-response short answers by the computer.

Rationale This proposed usage could bring to the teachers the benefits of

- reduced marking load,
- statistics being gathered for test and item analysis, and
- automatic recording of marks to a marks record program.

The ease with which these benefits are gained by the teachers appears dependent on

- the reliability of the scoring system,
- the complexity of the operation of the marking system, and
- the turnaround time for test marking.

The restriction frequently mentioned by the science teachers in the study as being most significant in determining their involvement in using a computer was the time available for learning about and using the system. If a teachers' aide is not available, the teacher must balance the benefits to be gained against the time required. The Scan-Tron stand-alone reader uses less time than a teacher would need to personally mark and release raw scores for a test. Generally, for a greater amount of information about the test, a greater investment of time to call up a program or to send the answer sheets to a central test-scoring facility is required.

Implementation Students' limited-response answers can be most reliably marked if the answers are directly keyed by the student into the computer terminal. The obvious requirement for access to hardware will restrict this option for most students and teachers. If, however, a mark sense sheet is used to record the pencilled selections, the teacher will need to instruct the students about the hazards of light or random pencil marks on the sheets and to monitor the reported results.

The reliability of the computer to mark short answer responses is more difficult to assess because of the possible variation in the thoroughness of the marking routine used by the program and the extent to which the program development team had anticipated the students' alternate responses.

Because the quality of a test is dependent, in part, on the reliability and validity of the test questions, the computer can support this quality-checking by reporting back to the teacher the students' responses and a variety of performance statistics, including the questions' difficulty level and discrimination index. These values, when combined with subjective comments from the students when the test is reviewed in class, provided the interviewed teachers with the support required for revision or rejection of a specific test or item or the normative data for referencing of students' performance over a period of time.

Most teachers quickly develop mechanisms for manually marking limited response test answers, including circles on transparent overlays or punched/slotted answer sheet overlays. A teacher should know that any computer-assisted alternative that is more complex or less accessible than these primitive, but functional, devices must offer compensating advantages that the teacher regards as worthwhile. The teacher should also be aware that the benefits of computer scoring of tests may lead to overuse of this mode of testing to the detriment of a balanced testing and hence instructional program.

Knowing that students react positively to early feedback on their test performances would also need to be considered by a teacher when deciding on the method by which a computer could be used to score the students' tests. In some cases, manual marking and recording may precede a more leisurely and thorough analysis by a computer system.

Illustration The simplest system for test scoring that was found in the teachers' schools was a self-contained Scan-Tron unit that yielded only raw scores. To produce test statistics or to record test marks, a computer must be attached to the reader and a program activated to process the data. For these more complex, and more productive, test-scoring systems, a knowledge of the protocol used by the system to achieve the marking is required. Instruction in this technical area is usually available in the operating manual or may be given by designated personnel who supervise the system.

A significantly more powerful system was also identified at the central office for one of the school districts. Tests sent to this facility for scoring require minimal teacher preparation of sheets for answer key and class identification. After less than a week turnaround, ample results including student and class performance are returned.

Test Records and Determination of Course Marks

Definition In this use, the computer will process data in the form of students marks and combine these marks, according to weighting proportions prescribed by the teacher, to calculate interim or final marks.

Rationale For a teacher who intends becoming acquainted with using a computer, this use, as a first time encounter, offers the advantages, if sufficient access to a computer is provided, of

- practice at a time and place convenient to the teacher,
- the option to seek assistance or to go it alone,
- immediate payoff for the teacher of a task that must be done before the course is completed, and
- interim benefits for the student in the form of notice of current standing.

An issue to be considered by a teacher considering this use concerns the possible changes in marking or reporting routines likely to occur if a marks records program is used. By making the calculation of student's marks easier, several decisions should be made early in the implementation of this computer-assisted reporting:

- Is more frequent progress reporting to students or parents envisaged? Increased access by students to their marks caused some increase in student expectation of mark reporting frequency. Automation of the calculation of marks involves increased time for both the teacher and the computer in processing these interim progress reports.
- Will marks be posted in the classroom for general perusal? Will the right of privacy of student's marks be recognized? What measures will assure this anonymity? The marks record programs usually sorted students alphabetically but varied in their ability to accept an alternate I.D. and further to sort the printed results by these identifiers.

The answer by the teacher to the questions posed above will define much of what the teacher will need to know about the impact of the use of marks records for both the teacher and the students.

Implementation Both the specific marks records programs and the general data-processing programs require a familiarity with the process of using a keyboard and disk media. Although the computer has been described as an "electric pencil," for some initial users of computers, the grasp is difficult.

Illustration This documenting of the learning achieved by students, part of every level of accountability in the school, gave the interviewed teachers much impetus to try out the mark recording programs that are so freely available. A common source of programs was from the local computer dealer as public domain "freeware." These programs are frequently the products of programming exercises and, because no controls were required for design or performance criteria by teachers, suitability of these programs for the intended application should, unless other users are known who can witness for the program's performance, be judged on the basis of "you get what you pay for."

The interviewed teachers referred to several programs, such as Class Records or Compumark, that were produced to overcome the difficulties present in those from the public domain collection. These copyright creations usually have been validated by teacher use and, in promotion in the market, usually mention this feature. Later versions of these menu-driven programs have also been revised on the basis of feedback from teacher-users.

Another source of software are the non-specific data-based programs, e.g., The Manager, or spreadsheets, e.g., Visicalc. Teachers require a higher level of skills for formatting and using these multi-purpose programs but some express a preference for the amount of personal control that this gives them over the processing of the students' marks. Concerns such as "only integers allowed" and "marks must be over 5%" are not present when the teacher defines the functions used for each of the operations.

Test Item Analysis

Definition Part of many test scoring programs is the option for a statistical analysis of the students' performance on a test to determine the levels of difficulty and discrimination of individual questions in the test and for the reliability of the complete test.

Rationale As defined in the questionnaire to the teachers, the purpose of item analysis is to provide evidence of the quality of the test items to enable revision or maintenance of a robust test item bank. As such, the purpose of item analysis goes beyond the conventional classroom teacher's concern for test analysis that yields a whole test mean average and standard deviation.

Implementation No knowledge of computer operation, programming, hardware, or software was required for this application. The knowledge and skills required by a teacher to use the complete statistics provided by a test analysis program would, however, include knowing

- the significance of the information that is available,
- the criteria to be used to evaluate the information presented,
- the limitations on the interpretation of the information that is available, and
- the techniques for revising questions using the above information.

This understanding is normally found in a course or a unit on measurement and evaluation and is not in the domain of computer knowledge.

The levels of information released from a test or item analysis then are each useful for various purposes including possible revisions based on distractor, item, or test responses. To be completely successful at this test item revision, a teacher would have to know how to use the information presented in the statistics (with a background in measurement and evaluation), have mastery over the course content, and have an understanding of student learning behaviour.

Illustration This analysis is an option available, on request, from test-processing services of mark-scoring microcomputer programs or district mainframes.

The information that is available from item analysis are used at several formal and informal levels of test item maintenance. Most of the interviewed teachers indicated they had focussed on specific test questions when they worked on large-scale school, district, or provincial test development committees. A teacher who is considering revision of test questions at a classroom level should be aware of the relationship between the reliability of statistics and the size of the population surveyed. Commonly, one district recommends a minimum of 100 students for a dependable interpretation. Thus, at a school level, a full set of statistics would be useful when revising final or common exams.

Because of the noted limitation of reliability of narrow-based statistics, test marking systems at either the microcomputer or mainframe level may offer an intermediate level of analysis of tests, identifying only the proportion of all students to pass each question. This identification of the "hard" questions and the subjective evaluation by students during class discussion may, as noted in a previous section on Test Scoring, enable the classroom teacher to revise or retain test items or to re-teach the concepts on which the test was based. The experience of the teacher is also significant when interpreting test results according to an observation by a teacher in the study that, although the computer program knew that the students were having difficulties with concepts, the teacher frequently knew why the students were having difficulties.

Correlation of Marks and Analysis of Trends

Definition In this use, computer systems are used for tracking course achievement by students, individually and collectively, over time.

Rationale The purpose of this longitudinal collection of data is to give a basis for instructional decisions regarding school programs. Primarily administrative in its scope for monitoring achievement in the classroom and school, this use holds promise,

- firstly, for those school personnel whose interests encompass, and go beyond, those of the classroom teachers' concern for the progress of individual students and,
- secondly, for teachers who intend to monitor the progress of their students for the purpose of instituting changes in the curriculum as it is practiced in the classroom.

Implementation The requirements for this use of a computer program, labor for data entry, memory allocation, and time for analysis require means beyond those that can currently be mustered by individual teachers. All of these factors are, however, capable of being overcome by allocation of resources. For example, the data on which generalizations of the adequacy of the program of studies is based are increasingly derived from testing programs that maintain this information in a data base. The process of initiating analysis of trends by school-level personnel must, then, for reduction of clerical staff for data entry, be preceded by the release of this information in its electronic form to responsible local personnel.

Illustration As an example of the analysis of trends using a computer, statistics for the diploma exams for the high school science courses at the grade XII level are regularly released to the schools and teachers in printed form within two months of the date of writing. These results show individual student performance on specific content and cognitive level of questions, as well as on the whole test.

With the full employment of the computer in this area, these results could be downloaded in a file to the school or district computer for local processing. Once the data is available, analysis of results from a variety of perspectives becomes possible. A teacher may, for example, wish to determine the effect on the level of specific skills or concepts developed by a group of students that received a treatment of a series of activities designed to increase their ability in that area. By selecting the relevant data, a comparison between this group and a control group in the large population of students could be made and from this comparison, plans could be made relating to this the next year's students' program.

Summary

Several learning requirements emerged as being fundamental knowledge about computers that were common to several uses and included

- an orientation to the control and care of the program disks and equipment,
- recognition of the signs and appropriate treatment of malfunctioning components,
- knowledge of the overall structure and flow of the computer programs,
- re-immersion by the teacher as an active learner of the processes of education.

Specific knowledge was also needed by teachers in the separate uses of computers including the

- evaluation of the benefits and costs associated with each use,

- clarification of the objectives to be achieved by using the computer, and
- operation of the specialized programs,
- employment of specialized peripherals for various applications,
- unique requirements of students who are using the computer programs,
- appropriateness of the uses of the computer for particular educational conditions.

CHAPTER VI

Summary of the Study

This study has attempted to identify what a teacher should know who intends using computers effectively in teaching science. The information on computer use in science was obtained from relevant literature, from teachers of science with some experience in computer use, and the researcher's own background and experience in the area.

The study began with a survey of current literature, as a result of which eighteen uses of computers for teaching science were identified. They were categorized under three phases of teacher activity: preparation for teaching, the teaching/learning act, and testing and evaluation. This was followed by the collection of data from teachers who had some experience with computer use in science. During the pilot stage of this data gathering, eight teachers were interviewed to

- revise the description of the uses of the computer by science teachers,
- evaluate the usefulness of using two methodologies (questionnaire and interviews) for collecting data in the main stage, and
- refine the interview procedure.

A questionnaire (Appendix A) was constructed for the purpose of gathering information on the nature and extent of the teachers' activities in using computers in teaching science and the issues in the uses of computers in teaching science that should be a focus for later discussion. The information from the questionnaire was also used to identify the teachers to be interviewed in the main stage.

Seventy-five teachers of science were selected for inclusion in the study by

- self-nomination by colleagues of the researcher,
- referral by the teachers' employing school district, and
- nomination of other interested teachers by participants.

A copy of the questionnaire was sent to these teachers. Fifty questionnaires were returned. The response information was tabulated (Appendix B) to indicate the extent to which each of the eighteen uses was prevalent in the professional activity of the teachers, as well as their perceived feasibility of each use. The following were found to be the most prevalent uses: test records, test production, curriculum planning and materials preparation, instructional management applications, simulation, drill-and-practice, and tutorial. Teachers were also asked to write in information relevant to computer uses. This was combined for analysis with the interview data obtained from the pilot and main stages.

On the basis of their questionnaire responses, thirty teachers were interviewed during which they described their experiences and projections for the learning needs of science teachers. Audiotapes of these interviews were transcribed and comments were sorted according to the type of use of the computer and the categories of knowledge underlying the use.

Much valuable information was obtained from the teacher interviews on most of the eighteen uses identified in the questionnaire. In addition, a number of categories of general knowledge for computer use were identified.

The study culminated in an framework for what a teacher should know to use computers effectively in science instruction. This is presented in Chapter V. Data from the three sources mentioned above were collated and integrated to give as comprehensive a description as possible on the following uses:

Phase I: The Preparation for Teaching: curriculum planning and materials preparation, professional development, communication between teachers and/or schools, information retrieval, instructional management.

Phase II: The Teaching/Learning Act: problem solving, simulations, tutorial, instructional gaming, drill-and-practice, electronic chalkboard/calculator, laboratory instrumentation, experimental analysis.

Phase III: The Testing and Evaluation: test production, test scoring, test records and determination of course marks, test item analysis, correlation of marks and analysis of trends.

The following categories of general background knowledge were identified because each one applied to more than one use: operating and programming, hardware and peripherals, software and courseware, word processing, inter-computer communication, implementation of application, and impact on the teacher.

Implications of the Study

A highly significant finding in this study is the low level of use of computers by teachers of science at all grade levels. The seriousness of this situation is heightened by the fact that this finding is for a sample of teachers who were considered to be the most advanced in the province in using computers for instructional purposes. A reasonable conjecture is that the majority of teachers of science have made very little or, more likely, no use of this new and powerful technological device.

This study also reveals that the teachers in the sample entered into computer use in a somewhat trial-and-error, random manner. Many motivations underpinned this process, such as, an innate interest in electronics, a desire to be at the frontier of professional innovation, the influence of peers who were using computers, and other personal factors.

This study also found some deficiencies in the articulation between the innovative teachers attempting to implement computers in the science instruction and other staff in the school and the district. This isolation resulted in an increased workload for the subject teacher and some fragmentation of the learning activities of the students with the resultant diminishment of the contribution of the computer in the learning enterprise.

The significance of this study is that it presents a coherent and comprehensive framework for the knowledge needed for computer use by teachers of science. This framework which is elaborated in Chapter V can be used as a nucleus for a curriculum for teachers to become competent users of computers. It is relevant to those who are already using computers to some extent as well as to those who are embarking on this avenue of professional development. Obviously, the framework can be used as a basis for the pre-service and in-service education in computer use of teachers of science. Because the study has uncovered many of the determinants underlying the implementation of computer use, its framework can be used to guide school boards and administrators in the provision of hardware, peripherals, and software of the kind and amount that will enable teachers to use computers effectively in science instruction.

There are three restrictions to be placed on the worth of this study. The first one is regarding the efficacy of computers for students learning science. In this study, the assumption was made that, indeed, computers do facilitate science learning. To ~~some extent,~~ this assumption is justified since the teachers in the sample were highly dedicated professionals to whom the ultimate worth of anything in teaching was judged on the basis of its impact on student learning.

The second restriction is in regard to the application of the view of "state of the art" to the framework for computer use in science as elaborated in Chapter V. Obviously, this view can be applied only in a limited sense. Only the experiences of *some* of the most dedicated users of computers in Alberta science classrooms were gathered in this study. In addition, time would allow getting only some of these experiences on tape during the interviews. The literature as well as the experiences of teachers on computer use are growing, both in quantity and in quality. The literature, unfortunately, is long on theoretical/conceptual ideas but short on concrete, practical experiences of teachers. The latter are certainly a more important source of information for teachers who are attempting to implement computers but, as this study has indicated, it is no easy task to keep tapping the experiences of teachers so as to broaden and deepen the framework for computer use in science instruction.

A third restriction relates to the presumption that knowledge alone, as identified in this study, is sufficient for the successful implementation of computers into the science activities of the teacher and student. There may be other dimensions to the implementation process and to the functional paradigm of the teacher who uses computers in science instruction that have not been identified in this study.

Suggestions for Further Research and Development

1. There is a need for considerable research on the impact on student learning accruing from the use of computers in science instruction. Obviously, a compilation and elaboration of uses of computers and the determinants of implementation underlying these uses must rest on their measured effectiveness in promoting student learning.
2. A process should be set into motion for the continuous gathering of experiences from teachers on their use of computers in science. This would be best done on a provincial basis involving a clearinghouse connected to teachers through a network of electronic mail and bulletin boards. This process should be coupled with a continuous revision of the body of knowledge, including

that relating to recent hardware and software developments, that a teacher of science should have so that (s)he may use computers effectively.

3. Professional development must be greatly increased in the use of computers in science instruction. Many avenues for this professional development must be devised. One avenue that stems directly from this study is the development of a high quality independent study module on each of the eighteen uses discussed in Chapter V. These modules could also be used for the pre-service education of teachers of science.

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Appendix A

The Questionnaire for a Survey of Teachers Using Computers in Teaching Science

(For the Main Stage of the Study)

Questionnaire

for A Survey of Teachers Using Computers in Science Teaching

This survey attempts to identify your unique experiences and interests in the uses of computers in science teaching.

The attached questionnaire includes a brief summary of eighteen possible uses of computers, according to a recent review of the literature. These general descriptions of uses of computers are provided to assist you in completing the questionnaire. Space is available in the questionnaire for your description of your other possible uses.

The eighteen possible areas of use of computers have been grouped within a framework of three phases of teaching activities that will be familiar to all teachers: preparing for teaching, teaching, and testing and evaluating.

Following each of these descriptions of uses, you are asked to identify your interests and activities in that use. The Guidelines for Responses on the next page is provided for your assistance in completing this section.

When you have identified yourself at the bottom of this page and have completed your responses on pages 4 through 15, return this questionnaire in the enclosed envelope.

If you are aware of other teachers who could contribute to this survey, please write their names and addresses on the reverse side of this sheet.

Thank you for participating in this survey!

A. Allan PEET
5604 - 94 Ave
Edmonton, AB
T6B 0X6
(403)469-3320

Participating-Teacher Information:

Teacher's Name: ______________________________

Subjects Taught: ______________________________

School Name: ______________________________(Elem/JrHi/SrHi)

School Address: ______________________________

School Telephone Nr.: ______________________________

School District: ______________________________

Guidelines for Responses

Following the description of each of the possible uses for computers in science teaching, a response section is provided to assist you in indicating your interests and activities in these areas. Use the interpretations below while completing your responses.

a) Indicate your degree of involvement with each area of use of computers by circling a numeral, 0 through 4, where 0 means none, 1 means a little, 2 means moderate, 3 means considerable, 4 means with a consuming passion!

b) For each area of use of computers where you rated your degree of activity or experience as 1 through 4, circle the letter (or letters if more than one applies) to indicate the type(s) of current or past participation by you in your science teaching activities. Use the list below when indicating your type(s) of participation:
U = User -(of purchased or authored programs.)
D = Designer -(defining objectives and branches, formatting screen displays.)
P = Programmer -(coding or revising programs.)
C = Consultant -(offering inservices or informal support to other teachers.)
O = Other -(not included in the four types above.)

c) Circle the number/letters that best indicates the potential that use has for you in your teaching activities, i.e., the feasibility, for you, of future implementation of that use. Use the interpretations below for the numbers in the scale:
+3 I am very interested in and will be personally attempting to implement this use of computers.
+2 I will try this use if the right conditions (e.g., time off, budget assistance, etc.) are available.
+1 I will probably employ computers in this area of use in my teaching on only a superficial basis.
0 I definitely do NOT anticipate incorporating this use of computers in my teaching activities.
NR I am uncertain and unable to indicate, at this time, my reaction to this use of computers in teaching.

d) Write the name of any relevant computer program(s) or briefly describe the software that you have used or have considered using.

e) Add any comments you think will be helpful in describing the computer use or your type(s) of activities or experiences. If the length of your response to any area of use exceeds the spaces provided, please use the reverse side of the sheet to complete your comments.

f) For uses of computers with which you have an interest or experience that are not included in the typical uses described, use the 'Other Uses or Activities' section at the end of that Phase of teaching.

The Uses of Computers in Science Teaching

The stages in the teaching process, namely, goal identification, objectives development, lesson design, lesson implementation, lesson evaluation, and lesson modification are grouped, for this study, under three phases: you are getting ready to teach, you are teaching, or you are evaluating the results of your teaching for each group of students for which you are responsible.

The uses of computers which form the basis for this survey are thus classified within these phases of teaching:

Phase I: The Preparation for Teaching;
  Curriculum Planning and Materials Preparation,
  Professional Development,   Library Applications,
  Communication between Schools and/or Teachers,
  Instructional Management
Phase II: The Teaching/Learning Act;
  Laboratory Instrumentation,   Simulations,
  Drill-and-Practice,   Problem-Solving,   Tutorial,
  Electronic Chalkboard/Calculator,   Gaming
Phase III: Testing and Evaluation;
  Test Production,   Test Scoring,
  Test Records and Determination of Course Marks,
  Test Item Analysis,   Career Guidance,
  Correlation of Marks and Analysis of Trends

These applications of computers, as described on the following pages, appear as mutually exclusive although, in any specific application, the combined contribution of several features is possible. For example, a simulation, with graphics, may appear as part of a tutorial with records of the student's responses retained in internal files or, perhaps, the use of a computer controlled 'intelligent' videodisc showing slides or moving sequences as visual prompts for, or as responses to, a student's comments in a drill-and-practice sequence.

Phase I:
The Preparation for Teaching

Prior to meeting with the students in the class, most teachers, whether utilizing computers or not, make decisions relating to

- the selection of course content and sequence,
- the choice of an appropriate teaching methodology,
- the preparation or selection of suitable materials, etc.

Here the computer may be an aid by getting information from a local or district memory bank or available diskette. This stored information may be entered or retrieved using Word Processing Programs or Higher Language programming.

Curriculum Planning and Materials Preparation

This function stores information about instructional materials in files in the memory of a large computer or on a diskette for a small computer. Upon request by a teacher, a copy of the instructional materials is displayed for selection and, if suitable, is printed for student use. Materials available could include worksheets, student notes, graphics, etc. The resource file that is accessed may also contain suggestions for the teacher regarding relevant media, references, or activities. Another possibility here is the local preparation of custom-tailored diagrams and illustrations using commercial programs.

Rate your degree of experience in this use:	0	1	2	3	4
Classify your type(s) of experience(s):	U	D	P	C	O
Estimate the potential for your future use:	+3	+2	+1	0	NR

Describe (or name) Software or Programs:

"I have personally used ________________________________
____."

"I would use if available ______________________________
____."

Other comments on your activities, programs, or this use:

____
____
____

Professional Development

The teacher also is a potential beneficiary of this collection of material in a data bank. The collective contributions of various colleagues and professional leaders become available, through modems and a regional network, for perusal and engagement in an in-service program supplemented with seminars (or 'round-table' multi-party conferences using the telephone connections).

Rate your degree of experience in this use:	0	1	2	3	4
Classify your type(s) of experience(s):	U	D	P	C	O
Estimate the potential for your future use:	+3	+2	+1	0	NR

Describe (or name) Software or Programs:

"I have personally used ________________________________
____."

"I would use if available ______________________________
____."

Other comments on your activities, programs, or this use:

____
____
____

Communication between Schools and/or Teachers

Closely related to the above professional development of teachers is the computer's capacity to aid in inter-institutional communication using the 'electronic mail-boxes' of a message facility into which specific- or group-addressed information is inserted for retrieval by the addressee(s) with their power for discretionary hard-copying. Included in this broad area of institutional coordination are maintenance of student records in school-district or -divisional computers.

Rate your degree of experience in this use: 0 1 2 3 4

Classify your type(s) of experience(s): U D P C O

Estimate the potential for your future use: +3 +2 +1 0 NR

Describe (or name) Software or Programs:

"I have personally used ______________________________

____."

"I would use if available ____________________________

____."

Other comments on your activities, programs, or this use:

____

____

____

Library Applications

In addition to administrative usage for resource management by library staff, a science teacher (or student) may access a data bank searching for (and cross-referencing) materials not included in the large curriculum resources records described above.

Rate your degree of experience in this use: 0 1 2 3 4

Classify your type(s) of experience(s): U D P C O

Estimate the potential for your future use: +3 +2 +1 0 NR

Describe (or name) Software or Programs:

"I have personally used ______________________________

____."

"I would use if available ____________________________

____."

Other comments on your activities, programs, or this use:

____

____

____

Instructional Management Applications

The assistance given to school activities by a Computer-Based Instructional Management System are desirable if individualized learning is the mode of activity in a school. The functions available within this general area include several of the elements described in the 'Testing and Evaluation' Phase of teaching including, not only such clerical tasks as Test Scoring, Test Records Maintenance, and Data Production for Analysis of Trends in a student's marks but also, the supportive tasks of Diagnosis and Prescription and Grouping. Using a cycle of criterion-based test scoring, diagnosis, prescription, and reporting, this application, which relies on educational objectives-dependent procedures, materials, and measuring instruments, seeks to provide the means by which the teacher manages the educational enterprise so as to offer each learner an optimum set of educational experiences. The suggested experiences may include materials or activities for an individual student or for a number of students who may be temporarily grouped in a shared learning situation.

Rate your degree of experience in this use: 0 1 2 3 4

Classify your type(s) of experience(s): U D P C O

Estimate the potential for your future use: +3 +2 +1 0 NR

Describe (or name) Software or Programs:

"I have personally used ______________________________

____."

"I would use if available ____________________________

____."

Other comments on your activities, programs, or this use:

____

____

____

Other Uses or Activities in 'Phase I' of Teaching

Rate your degree of experience: 0 1 2 3 4

Classify your type(s) of experience(s): U D P C O

Estimate the potential for your future use: +3 +2 +1 0 NR

(Please describe.)

____

____

____

____

Phase II:
The Teaching/Learning Act

The application, in the uses below, of computers to the process of teaching and learning will be present in either of two forms; Instructional Aid or Computer-Assisted-Learning, the distinction between these being the centrality, in the latter mode, of the computer to the direct instruction of the student.

Problem-Solving

Two meanings are attached to this term. One meaning is to solve mathematical problems. That is included under Drill and Practice below. In this study, only the other meaning is accepted, namely, the 'open-ended' use by a student of a computer in science education which is not limited by the pre-planned structure present in most other programs. For example, the student, using the computer, constructs a model of a real-world situation or system, e.g., writes a simulation, and then notes the degree of conformity to or discrepancy with the real situation. The construction of this environment frequently requires either programming skills by the student or a high-level language emulating artificial intelligence by the computer.

Rate your degree of experience in this use:	0	1	2	3	4
Classify your type(s) of experience(s):	U	D	P	C	O
Estimate the potential for your future use:	+3	+2	+1	0	NR

Describe (or name) Software or Programs:

"I have personally used ______________________________

____."

"I would use if available ______________________________

____."

Other comments on your activities, programs, or this use:

____

____

____

____

____

____

Simulations

When presented with a computer simulation, a student is an explorer searching for the rules underlying the system by noting the effect on the system caused by adjusting the programmed parameters available. A science teacher could offer the student a simulation as a 'pseudo-lab' when a demonstration or experiment

1. takes too long (e.g., genetics experiments),
2. happens too quickly (e.g., capacitor discharge),
3. is too dangerous (e.g., radioactive decay),
4. requires a complicated set-up (e.g., Millikan's oil-drop determination of charge/mass of an electron),
5. requires expensive or difficult-to-obtain materials or apparatus (e.g., Maxwell-Boltzman distribution of velocities in a gas),
6. occurs in a hostile environment (e.g., satellite orbits), or
7. causes undue stress to the environment (e.g., stream pollution.)

The usual purpose is to supplement 'normal' laboratory activities. There are also auxiliary uses of lab-simulations that include the possibility of

a) pre-lab orientation to equipment, procedures, and typical results,
b) lab-extension to expand the range of conditions beyond those experienced by the students when the lab was performed, and
c) post-lab replication of procedures and 'number-crunching' to verify experimental results.

This application may use the ability of the screen to exhibit, in addition to static alphanumeric characters, sketched figures which may depict animation.

Rate your degree of experience in this use: 0 1 2 3 4

Classify your type(s) of experience(s): U D P C O

Estimate the potential for your future use: +3 +2 +1 0 NR

Describe (or name) Software or Programs:

"I have personally used ________________________________

____."

"I would use if available ______________________________

____."

Other comments on your activities, programs, or this use:

____

____

____

____

Tutorial

The instructional (Socratic) dialog between the student and the computer utilizes the computer's enhanced ability for checking of the student's responses and branching for appropriate remedial discourse. The student responds to questions posed by the program; this program also has the capacity to evaluate the student's progress and to adjust the pace and extent to which the new material will be developed.

Rate your degree of experience in this use: 0 1 2 3 4

Classify your type(s) of experience(s): U D P C O

Estimate the potential for your future use: +3 +2 +1 0 NR

Describe (or name) Software or Programs:

"I have personally used ________________________________

____."

"I would use if available ______________________________

____."

Other comments on your activities, programs, or this use:

____

____

____

____

Gaming

The element of competition, either with the computer or with other students, provides motivation for a lesson. The determination of a 'winner' is the goal set by the program.

Rate your degree of experience in this use: 0 1 2 3 4

Classify your type(s) of experience(s): U D P C O

Estimate the potential for your future use: +3 +2 +1 0 NR

Describe (or name) Software or Programs:

"I have personally used ________________________________

____."

"I would use if available ______________________________

____."

Other comments on your activities, programs, or this use:

____

____

____

Drill-and-Practice

A major purpose of drill-and-practice programs is the maintenance of basic skills and concepts; matching of responses is required here as well as in the tutorial program. The branching for remediation and difficulty level is optional, as are diagnostic subroutines. In this study, practice at solving mathematical problems is included in this designation.

Rate your degree of experience in this use: 0 1 2 3 4

Classify your type(s) of experience(s): U D P C O

Estimate the potential for your future use: +3 +2 +1 0 NR

Describe (or name) Software or Programs:

"I have personally used -------------------------------

---."

"I would use if available -----------------------------

---."

Other comments on your activities, programs, or this use:

Electronic Chalkboard/Calculator

The presentation to a class of prepared notes and static or animated displays on a computer screen is an alternative to the film loop or overhead projector. The computer may also, in 'real-time' while teaching, calculate and display values of functions.

Rate your degree of experience in this use: 0 1 2 3 4

Classify your type(s) of experience(s): U D P C O

Estimate the potential for your future use: +3 +2 +1 0 NR

Describe (or name) Software or Programs:

"I have personally used -------------------------------

---."

"I would use if available -----------------------------

---."

Other comments on your activities, programs, or this use:

Laboratory Instrumentation

With the addition of appropriate interfaces to which may be attached sensors (transponders) or switches, the computer may record data from a variety of experiments, e.g., the acceleration of a moving object, the dissolved oxygen of a solution, the voltage and temperature of an electrochemical cell, etc. The computer may act as a fast recorder of these data or may also be programmed to analyze and display the data in a tabular or graphic form. The computer, again through interfaces at the output ports, may also control devices in an experiment, e.g., the release valve on a buret, an electromagnetic gate on a kinematics apparatus, a heater in a solution, etc.

Rate your degree of experience in this use: 0 1 2 3 4

Classify your type(s) of experience(s): U D P C O

Estimate the potential for your future use: +3 +2 +1 0 NR

Describe (or name) Software or Programs:

"I have personally used ______________________________

____."

"I would use if available ______________________________

____."

Other comments on your activities, programs, or this use:

____

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____

____

Other Uses or Activities in 'Phase II' of Teaching

Rate your degree of experience: 0 1 2 3 4

Classify your type(s) of experience(s): U D P C O

Estimate the potential for your future use: +3 +2 +1 0 NR

(Please describe.)

____

____

____

____

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____

Phase III:
Testing and Evaluation

The after-learning-content uses of computers center on the utility of the computer to assist the teacher in the assessment of the student and of the educational program and the guidance offered to the student making a decision in career counselling.

Test Production

The possibilities available here are

a) for the computer to store and retrieve test materials (using a Word Processing Program or Higher Language programming) or

b) for the computer to generate unique questions using question 'templates' into which appropriate random values are inserted resulting in a limitless number of parallel test items all of which follow general and expected formats.

The materials stored in a) above may be whole, unit tests (which may be revised as necessary for the current usage) or individual test questions maintained in an item bank. Selection options for the teacher using the testing program are frequently

i) visual test-by-test or item-by-item search and revision by the teacher or

ii) stratified random selection of items by the computer with specified criteria constraints such as level of difficulty, weighting by subject matter objective, cognitive level, or type of response required.

Rate your degree of experience in this use: 0 1 2 3 4

Classify your type(s) of experience(s): U D P C O

Estimate the potential for your future use: +3 +2 +1 0 NR

Describe (or name) Software or Programs:

"I have personally used ______________________________

____."

"I would use if available ____________________________

____."

Other comments on your activities, programs, or this use:

____

____

____

____

Test Scoring

If the responses to the test items are multiple choice or true/false or if the test is given on the computer (on-line) and matching routines are available for short answers, then the answers may be scanned for scoring of responses.

Rate your degree of experience in this use: 0 1 2 3 4

Classify your type(s) of experience(s): U D P C O

Estimate the potential for your future use: +3 +2 +1 0 NR

Describe (or name) Software or Programs:

"I have personally used ________________________________

____."

"I would use if available ______________________________

____."

Other comments on your activities, programs, or this use:

____

____

____

____

Test Records and Determination of Course Marks

After scoring, the results may be written to internal records and/or returned to the test user; a computer managed system may also offer recommendations for units to be covered or reviewed based on item and test results. Following entry of weighting factors, interim or final grades may be calculated.

Rate your degree of experience in this use: 0 1 2 3 4

Classify your type(s) of experience(s): U D P C O

Estimate the potential for your future use: +3 +2 +1 0 NR

Describe (or name) Software or Programs:

"I have personally used ________________________________

____."

"I would use if available ______________________________

____."

Other comments on your activities, programs, or this use:

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• Test Item Analysis

The records of results in the tests may be subject to the analysis of students' performance by software statistical analysis packages to determine the level of difficulty, quality of discrimination, etc., enabling the revision or substantiation of the items in the test bank.

Rate your degree of experience in this use: 0 1 2 3 4

Classify your type(s) of experience(s): U D P C O

Estimate the potential for your future use: +3 +2 +1 0 NR

Describe (or name) Software or Programs:

"I have personally used ____________________________

____."

"I would use if available __________________________

____."

Other comments on your activities, programs, or this use:

____

____

____

____

Correlation of Marks and Analysis of Trends

Records of performance results on tests allow for the longitudinal tracking of individual student's achievements and the comparison between groups which may form a basis for instructional decisions regarding school programs.

Rate your degree of experience in this use: 0 1 2 3 4

Classify your type(s) of experience(s): U D P C O

Estimate the potential for your future use: +3 +2 +1 0 NR

Describe (or name) Software or Programs:

"I have personally used ____________________________

____."

"I would use if available __________________________

____."

Other comments on your activities, programs, or this use:

____

____

____

____

Career Guidance

Although career counselling of students does not normally fall within the domain of activities of classroom teachers, the science objectives frequently include references to occupations and industries where a knowledge of science is a prerequisite. The CHOICES pre-employment and training information service is the most common program used by schools offering this resource.

Rate your degree of experience in this use: 0 1 2 3 4

Classify your type(s) of experience(s): U D P C O

Estimate the potential for your future use: +3 +2 +1 0 NR

Describe (or name) Software or Programs:

"I have personally used ________________________________

____."

"I would use if available ______________________________

____."

Other comments on your activities, programs, or this use:

____

____

____

____

Other Uses or Activities in 'Phase III' of Teaching

Rate your degree of experience: 0 1 2 3 4

Classify your type(s) of experience(s): U D P C O

Estimate the potential for your future use: +3 +2 +1 0 NR

(Please describe.)

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Appendix B

Tabulation of Questionnaire Responses
Reported by Use of Computers

Phase I:

Curriculum Planning and Materials Preparation:

```
Teacher Identifier:
00000000011111111112222222222333333333344444444445
12345678901234567890123456789012345678901234567890

Degree of experience:                               x X x x
13102003210024204310232001133130141220331111130301 0 1 2 3 4
                                                  1315 811 3
Type of experience:
.UU....U.U..U.U.U.U.UUU..U.UUUUUU..UUUU.UUUUUU.U.U
.......D....DDD......D...D.......D.D...DDD.....D..
P......P....PP...P.......PP.P.....P.....P.........
.CC....C....CCC......C...........C....C........C..
....O.......O.......O..........................O.

Potential for future use:                               x X
233.2323323233.233.2.332.12.312333321333321323.322 0 1 2 3
                                                   0 41524
```

Open Responses:

I have personally used:

02:APPLE WRITER, BANK STREET WRITER
05:CRIB.
08:Word Processor, DBMS, Self authored worksheet preparation.
09:MECC materials for test generation.
10:a computerized list of materials in our school library.
13:"PLATO-based" courseware, i.e., Elem. Physics, Fraction Tutorial, Estimation Program.
15:My own materials and GAS LAWS and K.M.T.
17:"SUPER TEXT" word processor to prepare labs, tests, outlines, etc.
18:Various of my own (and others) worksheets and experiments, nothing commercial - locally produced.
19:TEACHER UTILITY, Michigan Education Consultants Consortium (1982).
21:EPSD item banks. Some stuff from Ainlay - Alchem
22:Data base programs for A-V materials (File Cabinet); Word Processors - Screen Writer + Gutenberg.
23:APPLE WRITER, SCREEN WRITER II
26:my own data files.
27:Text files created by me or VISICALC.
28:APPLE WRITER II(E), IBIS.
30:Material would have to be collected on a narrow basis - would only use 1 science.
31:Test - Word Processing Files - Apple, IBM, & Commodore, (APPLE WRITER.)
33:Electric circuit problems.
34:Super-Text and Gutenberg.
35:Word Processing package.

36:the Merlin Commodore Series.
37:I.E.P. MANAGER
39:MAGIC WINDOW II, CLAS AUTHORING SYSTEM, PFS WRITE, WORDSTAR, APPLEPLOT.
40:Word Pro as a basis for design of work for students Labs, Exams.
42:JUGGLER IIe with LEXICHECK.
43:media references.
44:Paperclip.
45:Word processed assignment sheets (my own) - easy to modify & change.
46:PFS File and Report. Applewriter.
48:AppleWriter, Visicalc, SuperText, Create a Test.
50:and have been involved in a University program where our computers linked up to their Mainframe.

I would use if available:
05:The regional council had discussed application. I have also contacted [Systems Personnel] about this idea.
08:programs.
09:Chemistry program if it could handle capitals and subscripts.
10:lists of all school material readily available.
15:Good quality programs tailored to the objectives.
16:Any suitable program.
18:Any others I could find.
21:materials on Floppy discs like graphics, worksheets.
24:Lists of A-V correlated with curr.
26:suitable materials.
27:IBIS.
33:Supplementary problems for students; student handouts.
36:Apollo Series
38:any programs I could find - I haven't found any yet.
48:Data base or file program - Apple Works.

Other comments:
01:For test development-references-activities.
02:Currently writing a unit for EPSB on contract on 'energy.'
03:PLATO Chemistry Lessons offer some ideas for own lessons, Materials preparation (worksheets, etc) using a word processor (GUTENBERG.)
04:This possibility of computer use is futuristic and down the road in EPSB system or province. I do not forsee programs developed which would be curriculum compatible unless one replaces current AV materials with computer assisted presentation or selection. The cost is astronomical and long time in coming. Who will prepare this curriculum information? Consider how slowly the Chem Item Bank emerged and how much more could be done.
08:A major area of my use.
09:I have completed Physics 20 worksheets and tests. Diagrams are most difficult to handle.
13: I have a "vectors" routine including tutorial and

practice which I wrote and used 5/6 years ago.

14:My Physics 10 and 20 course is completely on disk. I am revising it and it will be published as it has been approved for use in Manitoba.

17:This is a very satisfying use of the computer. It enables me to accumulate an interesting repetoire of materials and to update them on a continuous basis. (I spend about 2 h/day working with the word procesor - 4 d/week).

20:I have just acquired a Gutenberg Jr. and in the process of learning to use it.

22:There are lots of possibilities here and I am constantly expanding my use of this area.

26:Not a major computer use - print materials are fine here.

28:The word processor program has a full range of easy to use commands plus on screen help pages. IBIS allows nonprogrammers to write tutorial or drill and practice lessons.

29:I use word processors to prep worksheets & notes.

34:This application has the greatest potential for — increasing the quality of education of any other computer application - no question.

35:I just got my printer & word pro, so I'm only starting the process of organizing & using the capabilities of the computer in this area.

36:I am designing my own software right now - simulations of experiments.

37:Useful for Individual Curricular Objectives Setting.

38:I would even be interested in developing these as the ones I have seen on the market are poor.

41:Home-made

42:Bio teachers in our department are using a locally developed "individualized" Biology program.

50:This program allowed me and students to communicate with a professor (expert) there using a storage file back. My questions stored there, and answered for the next day. It was very time consuming as it was set up.

Professional Development:

```
Teacher Identifier:
00000000011111111112222222222333333333344444444445
12345678901234567890123456789012345678901234567890

Degree of experience:                               X
..10000000000000030000000000000010031200210000002000 0 1 2 3 4
                                                  39 4 3 2 0
Type of experience:
..U.............U............UUU..UU.UUU..........
................D................D................
..........................P.......P...............
..C..............................CC...........C...
........O..O.......O.....O......................O.

Potential for future use:                            x X x
1.1.132222312232.31...22..232..32332.3122.0.1..122 0 1 2 3
                                                   1 817 9
```

Open Responses:

I have personally used:
15:VISITERM and modem for use on Altel Data's ENVOY.
17:Same as above and "home brew" software primarily for simulation purposes.
19:TEACHER UTILITY, M.E.C.C. (1982).
27:None.
28:Nil.
30:I took an education course several years ago where the course was centered around a telephone connection.
31:ASCII EXPRESS, Novation Com-Ware
33:budget & suitable computer.
34:our school data bank extensively.
35:IBIS, test generator programs, tutorials for computing science.
40:Data on Main Frame for exams in Math.
47:Class Manager, Visicalc, Word Pro 64, Word Pro 4.

I would use if available:
16:Any suitable program.
17:A good filing or data base program for bibliographies and indexing journals.
18:Anything.
24:as indicated above (Curric Planning & Materials Prep'n.)
27:On a reasonable cost.
31:SOFTTERM
34:a modem.
35:any of the above.
38:anything.
40:Data for Science.
47:Paper Clip, Delphi Oracle.
48:Test banks - Lesson Plans (CRIB style.)

Other comments:

02:Activity = 2 if this includes using a computer to develop personal programming skills.
03:PLATO System Demonstrations in Science Lessons.
04:School not connected to central data bank via modem except for administrative records but not professional use. Will the costs justify or improve existing methods?
09:We have no hookup at present but are examining use of modems for transfer of marks to Dept of Ed. The use you have mentioned would seem highly desireable.
15:An excellent possibility but needs government support, e.g., Telidon.
17:Essentially the same as above.
20:Gutenberg and formating using Gutenberg is being used and will be used for ALCHEM revisions. I am not personnally involved in this aspect of printing of ALCHEM as yet.
22:I'm not sure what you mean here - do you mean ATA services + information via modem?
24:I like the idea of sharing ideas.
28:This area has a lot of potential.
29:I know of no data banks except the EPSB Phy & Chem & Bio test bank (avail in booklet form).
34:Our ALCHEM "data bank" will eventually be published. Our school data bank is used by the majority of teachers in our 12 teacher department.
35:The main problem is that the material that is available hasn't been organized by the school boards or Dept. of Ed. yet.
40:What is a Professional Leader?
50:This might relate to the area just above. I'm not sure; the way it is specifically worded, it seems it isn't.

Communication between Schools and/or Teachers:

```
Teacher Identifier:
00000000011111111112222222222333333333344444444445
12345678901234567890123456789012345678901234567890

Degree of experience:                              X
.0000000000010000101000000200300010200230100000000 0 1 2 3 4
                                                  39 5 3 2 0
Type of experience:
.................U.U......U....U.UUU.UU..U........
.......................................D..........
.............................P....................
..................................................
........O..OO............O......................O.

Potential for future use:                            x X x
.22.1322103.2.32311..2.2..3311.122.3.323220.0...12 0 1 2 3
                                                   3 814 9
```

Open Responses:

I have personally used:

20:CLASS RECORDS (Alphatel)
27:CLASS RECORD
30:Mail Box services on the U of C computer. Keep records of students marks.
34:Gutenberg to communicate with a phototypesetting machine.
39:Calgary Separate System Electronic Mail system.
42:"SAIT" Records Program.

I would use if available:

18:Accessed data on student records from EPSB records on students.
22:an inter-school or system exchange.
24:As indicated above.
26:prep time allowed it.
27:A program on attendance or some other software.
33:budget & suitable computer.
34:a modem compatible with Gutenberg.
38:Anything.
48:CRIB type resources.

Other comments:

03:Modem needed, useful for teachers at their homes.
04:Probably used to some extent by administration re. student records. This aspect will probably be developed in the next few decades more than any other via computer application but remains to be seen and developed by IBM, telephone companies, and others before one can react to its possible use.
09:Only one high school in district. However, any data that could be transferred to central office would be most helpful I'm sure.

15:I use electronic mail for my business but I am unaware of a data base shared by teachers.

16:This net-working idea is inevitable if the distributed systems pilot project is successful.

17:I would be very interested in exploring this "untapped" resource.

20:Above program used for maintenance of class mark records only.

24:Help to standardize courses. Reference for standards.

28:Our district currently uses the "D.B.Master" for student records and they are produced in hard copy and mailed in.

34:Teachers who have similar interests can share materials in this way and grow professionally when intra-school interests are not compatible.

35:Our school has used the school board's main frame for attendance & mark records.

36:About half of our staff is in process of transferring marks records to diskette.

40:Developing objectives for Bio 10/20/30 for Calgary Public for Main Frame. Also writing of items for Bank.

45:PetroCanada has this system. I see it as a long way off for us.

Library Applications:

```
Teacher Identifier:
00000000011111111112222222222333333333344444444445
12345678901234567890123456789012345678901234567890

Degree of experience:                              X
.000000002000001200000000000002001001000000002 0.00 0 1 2 3 4
                                                  41 3 4 0 0
Type of experience:
.........U.....UU.........U..UUU.U..UU.......U....
..................................................
..................................................
..................................................
........O..OO.......O.....O......................O.

Potential for future use:                                X
3212132222312.32331.22.2..21132220131322222222.232 0 1 2 3
                                                   1 82510
```

Open Responses:

I have personally used:
04:Replacing existing card catalogues by computer cataloging programs. Not aware of any titles.
10:Library data banks.
17:I have used SUPER TEXT for this and PFS FILER.
18:I am looking at some PLATO courseware.
26:microfiche.
27:None.
31:DATA FACTORY, MULTIPLAN
37:University research searches and data banks in medicine, physiology, etc.
42:ERIC
46:PFS File.

I would use if available:
15:A Cameron Library Data Base.
24:Listing of periodicals articles from back issues presently available at the school.
26:prep time.
27:In the school or county level.
31:LOTUS 123
33:budget & suitable computer.
38:Anything.

Other comments:
01:Possibilities are unlimited.
03:If an alternate to the Cardex System.
04:Library uses computer for resource management but data bank access by myself is zilch as is the library's on my behalf. Computer cataloging is about 1 year down the road. This aspect should speed up manual search considerably and space but terminal and production costs

may present widespread use.

09:Presently in process of acquiring hardware which may prove beneficial to librarian. Am not sure which program would aid in information retrieval.

17:I need this! I have a number of journals dating back to the early 1960s Scientific American, American Journal Physics, etc.) - I could use an index!

22:Good idea but will probably require implementation on a large scale to access data banks on minis and mainframes.

28:For inventory of books, yes. At an elementary school level, I would prefer the students to use a card catalog.

31:Film classification on the basis of 5 fields (Title, number, topic, subject, week of instruction.)

48:Our librarian is presently setting this up.

50:I know our librarian uses the computer to assist her record keeping of books on loan.

Instructional Management Applications:

```
Teacher Identifier:
00000000011111111112222222222333333333344444444445
12345678901234567890123456789012345678901234567890

Degree of experience:                               x X x
.01100003021000121 20.1.11.200231033320302212311201 0 1 2 3 4
                                                   161310 7 0
Type of experience:
..U.....U.U....UUUU.U..UU.U..UUU.UUUUUU.UU.UUUUU..
...................................DD..........D..
......................P...........P........P......
..C........C........C............C................
...O........O.O.................................O.

Potential for future use:                               X x
122323203.322.32223..233..22.23323332322322323231. 0 1 2 3
                                                   1 22118
```

Open Responses:

I have personally used:

03:PLATO PLM Series (Teachers learning BASIC.)
09:Marksheet, Alta Ed Reporting System and local program.
11:Apple GRADE BOOK and Alphatel MARKS MANAGER.
17:CLASS MASTER - Enable Software of Red Deer.
18:Some PLATO materials.
19:"Gas Laws and Kinetic Molecular Theory" Apple II Plus - D.C.Heath Canada.
21:CLASS RECORDS - Alphatel (Falk + van Kessel.)
23:"GRADES PROGRAM" which I have revised to suit my needs.

24:a marks program.
26:Some CoCo math programs.
27:None. CLASS RECORDS to some extent or VISICALC.
31:COMPU-MARK, CLASSROOM MANAGER.
34:Falk's and van Kessel's Grades Program marketted by Alphatel.
35:The APPLE Mark Sheet program as well as one developed by one of our students for the PET.
36:Commodore programs from Merlin and student-produced programmes in PSSC courses.
37:Chatsworth Card Reader Test Scoring Program. Super Pilot records.
39:CML System, Calgary Board of Education.
41:CML System (Calgary Board's management System.)
42:COMPU MARK (locally developed - Peters' Soft Products)
44:Paperclip.
45:COMPU MARK - Peters Software.
46:Commercial instructional programs; CELL DIVISION and MENDELIAN INHERITANCE.
47:LOTUS III.
48:Visicalc.

50:Milliken.

I would use if available:
09:HARTS System 3.
18:Anything pertinent.
24:as indicated above.
26:Apple/MECC, etc., stuff.
27:In the school.
33:for individualization of instruction.
38:Anything.
48:A good marks - data program.

Other comments:
04:Currently evaluating some biological systems disks for possible use in Science 11 classes. Perhaps computers are the answer to individualized learning modes but subject areas and concept areas will require development of compatible curriculum software. Maybe this should be the function of the correspondence branch in our province. Nothing will individualize instruction better than computers.
09:As far as diagnosis and prescription goes, this process takes considerable time to incorporate into subroutines. Availability of hardware presents problems also at present.
11:An excellent way to provide up-to-date reports of student achievement to students and parents on short notice!
14:Individualized learning is a nice ideal, but it seems too difficult a goal to accomplish at the present time. The spoken word, the actions accompanying the spoken word is a more efficient transmitter of information than reading off of print or conputer material. I think that there are advantages to having classes together. Each student doing their own thing at their own time creates more problems than it solves.
15:I am using a computer-controlled Laserdisc containing materials on biology and it has a tremendous potential for students on individual study.
17:We have used this type of system for several years primarily for clerical application - it has not been used to further individualized teaching.
21:I see this "administrative" aspect as a logical "in" for computer use by teachers.
22:Very few materials available here and hardware limitations don't help. This area has excellent potential for a significant group of students.
28:This area certainly has potential as long as it does not become the total focus of education. A good education must cater to student interests and needs and not always force them into a mold.
29:[`?' bracketed beside description of use.]
30:I evaluated math software through the Dept of Education
31:Have used MULTIPLAN & VISICALC for marks programs.
34:The immediate feedback to students provides motivation

and interest in marks.
35:I often program a mark calculator for specific use if I'm giving various percentages for different activities.
40:Would be nice.
44:Developed a mark-book program which is being used by myself and 3 teachers - others are planning to use it next report term.

Other Phase I Activities/Comments:

```
Teacher Identifier:
00000000011111111112222222222333333333344444444445
12345678901234567890123456789012345678901234567890

Degree of experience:                               x X X x
.2......4.0.....2001.320...3.....400..2.........0.  0 1 2 3 4
                                                    7 1 4 2 2
Type of experience:
........U.......U..U..................U...........
.D..............D..........D.....D................
.P..............P.....P...........................
.C...............................C....C...........
.....................O..........................O.

Potential for future use:                               X x
........3.3.....2.1...2..0.3.....3....2.........2.  0 1 2 3
                                                    1 1 4 4
```

Comments:

02:Writing Lab Chemical Inventory program.

04:I don't disagree with the above categories but they are futuristic. I would be interested in knowing which science teachers in the Edmonton System are in fact involved in these areas using computers. Computers are not yet a basic part of science labs or resource centres where this type of use is common practice.

09:Will use in scheduling, marks, attendance, etc., in administration extensively the HARTS III system. At present using Chatauqua Systems which is cumbersome and time consuming besides does not do all funtions required.

11:If C.R.I.B. material could be available in a Data Bank, it would provide a valuable resource which could be tapped almost at will.

17:I will prepare specific programs to simulate or calculate a specific quantity for a math or physics class. Most of my work is done using the computer as a simulator.

20:Limited use in maintaining class marks records.

22:I have been doing considerable work for the Computer Technology Group of Alta Ed. I also have accreditation from CEIMA for both software and text analysis. With the need for analysis and the large amount of information + products coming out, we need streamlined methods of making uses + products available to classroom teachers. Information retrieval via modems will be important.

23:Personally authored programs to test student lab calculations, an analysis.

28:I have used the "D.B.Master" program to keep track of and re-order the elementary science supplies for the school district.

34:Publishing of school textbooks.

45:["?" placed beside this sub-section.]

Phase II:

Problem-Solving:

```
Teacher Identifier:
00000000011111111112222222222333333333344444444445
12345678901234567890123456789012345678901234567890

Degree of experience:                               X x
0200001002003000200000000320030002021040111.00.001  0 1 2 3 4
                                                   32 6 6 3 1
Type of experience:
......U..U..U...U........UU....U...UUUU.UUU.......
............D...D........D........D...D...........
............P...P........P...P........P...P......
......................................C...........
........O..O..................O.................O.

Potential for future use:                              X x
.2122321.2333232331..1.2..2302.13322233132230..22.  0 1 2 3
                                                    2 61714
```

Open Responses:

I have personally used:

02:Computer Science Assignments.
10:Odessa Lake - a local hunter training program.
13:My own (generated) programs.
17:"home brew" programs and some material from MECC.
26:Various CoCo programs.
27:Optics, solubility product disks available from ACCESS on Science.
28:None on the market at elementary level.
34:ENER-CALC (prepared to my students.)
LAB ANALYZER (prepared to my students.)
CONSERVATION OF ENERGY (prepared by Gordon Knight)
36:Student-produced programs. TRS 80 programmes.
37:MECC - Odell simulations, Volcanoes.
39:Software developed by me or students.
42:Chem Nomenclature, Mole concept, Periodic Table Review.
50:LOGO, Rocky's Boots, The Factory, Bank Street Writer.

I would use if available:

12:Yes.
17:Any good program.
18:Anything and everything.
33:computer & software.
38:Anything.
49:`SchoolMasters' Michigan: "ECOLOGY, AST. & ARITH." and "EARTH & LIFE SC."

Other comments:

02:Limiting factor is knowledge of BASIC programming.
04:Useful possible mode but some ways to go to achieve. Probably a futuristic application.

05:Most students gain some sort of problem-solving "sense" when using computers. This seems to be in the area of learning how to program.

07:Milliken Math Sequences

13:The vast majority of what I have seen in this area is not very interesting.

14:There is good potential in this area if computers would be more available in class.

15:My sons used a software program called ROBOT WARS. With this software package, they had to design their own robot and compete with others to see who could design the best robot.

17:This is used most in my Physics and Math 31 classes. Students have studied shapes of graphs - projectile motion, orbital motion, scattering, etc. My Math 31 class uses computers the most frequently, ca. 1 hour/week and I have incorporated the use of the computer into the curriculum.

18:These types of things are extremely difficult to program so that a wide variety of input to the computer will be accepted. For instance - interaction between computer and student is not often allowed on an open-ended basis; he is forced to choose one of several given answers.

24:I have seen several programs of this type and feel they have some use, although limited. Mastery is quick and often programs do not extend far enough.

28:(of your model) This area should be the first real thrust of computers into the world of science.

30:I teach Computing Sciences and try to get students to use other subject areas for their interest. Because it is a 1st year course students have difficulty doing this. I may look at it again next year.

31:Not sufficient computer availability or quality software.

34:My students have prepared a program to mathematically model (simulate) low-energy, passive-solar homes and to check student calculation when checking the validity of the assumptions of conservation of mechanical energy and of linear momentum on an air table.

35:This could be used by the chemistry students I have in computing science. I feel this is extremely useful as the student must understand the concepts, restrictions, variables, etc., before s/he could program a simulation.

37:This use has the best potential application. Teachers need to input more of their needs in this area to producers.

39:Students do this for Special Projects Credit.

41:As students become more computer literate I believe they will be using and designing as they currently use fancy calculators and we in our day used only slide-rules.

44:Used an on-line system with paper printout to teacher some ideas of Physics 10 - basically dealing with projectiles.

Simulations:

```
Teacher Identifier:
00000000011111111112222222222333333333344444444445
12345678901234567890123456789012345678901234567890

Degree of experience:                                x X x
12210002200022212100020001210010130420420001023 00. 0 1 2 3 4
                                                   23 913 2 2
Type of experience:
U.UU...UU...UUUUUU...U...UUU.UUUUUUUUUUU......U...
.D.....D....DD.......D...........D.D..D....D.D....
.P.....P....PP..P....P............P...P....P......
.CC...........C..................C....C...........
................................................O.

Potential for future use:                              X x
1313232220332332230.23322133231033232332322323223. 0 1 2 3
                                                   3 41922
```

Open Responses:

I have personally used:

01:EARTHQUAKE

02:Created programs for earthquake simulation, falling bodies, etc.

03:Nuclear Power Plant, PLATO.

04:TITRATION Science Demo

08:VISICALC and programs written by self.

09:MECC programs on oil drop, heat loss, titration, etc.

14:Interference of waves, vector addition, Rutherford scattering, orbit of a planet.

17:Projectile motion simulation, sound wave synthesis - all have been home made.

18:A program written by a student (and guided by F. Jenkins) on cons. of momenteum.

22:MECC "COLLIDE" + various simulations designed by myself + others.

26:Odell Lake.

27:Millikan's oil drop, Titration, Radioactivity.

28:A few simplistic programs.

31:ACCESS materials - most is garbage.

33:Inclined Plane, "A" Machine, Light Waves, Thinking and Learning; from Educational Materials & Equipment Co., Pelham N.Y., USA.

34:1) MECC Collisions in 1-D Simulation.
   2) ENER-CALC (created by my students.)
   Lab Analysis (Checking.)
   3) Conservation of Energy
   4) Conservation of Momentum

35:a program for Experiment 19 on equilibrium for # crunching.

36:My own software and Commodore programs by Merlin.

37:A number of sophisticated computer-controlled flight

simulators.
39:Bison, Rats, Population, Whale, Bighorn Sheep, Odell Lake, etc.
40:GENETICS (mine), Air Table Simulations, Titration.
46:ECOLOGY (Simulations,) TRIBBLES.
47:Millikan's Exp, MECC disk, Heat Lost.

I would use if available:
09:any meaningful lab.
18:Anything and everything.
21:? lab + demo situations (micro) particle animations - circuits.
22:Chemistry - collision theory + various reactions; Physics - almost anything.
24:programs as mentioned above. Many possible applications.
27:suitable programs.
31:More PLATO software if enough were available.
33:budget, computer, software.
34:Collisions in 2-D simulation.
35:any good commercial package for situations as the above.
38:Anything.
40:Any other reasonable Simulation - Limits time, $, hardware, software.
49:Both of these [a) pre-lab orientation and b) lab-extension.]

Other comments:
02:Useful in teaching the concept of `a million' (using a counting loop.)
03:Students work at own pace for enrichment.
04:Have demonstrated titration simulation to indicate endpoint or equivalence but program used normal solutions so no longer used. Totally agree with the 7 examples used in explanatory notes as to what a computer could illustrate quickly and better than I could, e.g., sine waves. Better than films where only a portion is useful and where access to film (booking) is better. Depiction of motion is valuable characteristic, e.g., atoms bonding.
09:Nothing can replace "hands on" labs but nevertheless, the computer can affect the "hands on" procedures.
13:I have not kept elaborate records of titles reviewed, however, I do not care very much for the Physics simulation. I have a philosophical problem with, for example, simulating the Millikan Expt. This is probably the worst use of a computer in a Physics class. Actually, I could go on and on about this! The bottom line is that the majority of what I have seen in Bio. and Physics would be useless to me.
14:If the real experiment can be done, i.e., oil drop method for electron charge, a simulation is not as good in representing the real "flavor" of the experiment. If the introduction of the computer will decrease the experimental activities done by students with real

equipment, there will be no net improvement in science teaching.

15:There is a simulation using a nuclear reactor as well as some chemical reactors.

17:This is an exciting area to explore but it should be used with discretion. I would hate to see a student miss out on titrations just because the computer simulates it better. The Millikan Lab is another lab that should not be done as a simulation. Students miss much of the tacit dimension of science education when they don't actually handle the apparatus of scientific investigation.

22:In my opinion, this is one of the most beneficial areas of computer use. The ability to simulate ideas (free from practical limitations, i.e., friction in Physics) and the testing + manipulation of these ideas is a powerful tool.

24:Seems one of the more applicable classroom uses of the micro. Some programs of this type seem reasonably good.

28:This is one of the greatest potential areas for computer use.

30:Good idea - lots of graphics but when? I agree (with complicated setup use, e.g., Millikan's oil-drop expt.)

34:In my view, this is the second most important use of computers in the schools - after word processing.

35:They are developing some excellent simulations regarding the reading of scales, burets, etc., as well as simulations showing hydration, acid-base reactions, and diffusion & osmosis. These simulations are excellent and provide an excellent means for the development of process skills.

39:Most useful of all CAI type for high school use.

44:Used to simulate projectile motion.

Tutorial:

```
Teacher Identifier:
00000000011111111112222222222333333333344444444445
12345678901234567890123456789012345678901234567890

Degree of experience:                                x X
13210012000010111200110000120010111030311121010000. 0 1 2 3 4
                                                  2219 5 3 0
Type of experience:
UUU...U.....U.UUU...UU....UU.UUUUUU.UUU.UUU..U....
.......D............................DDD.D.DD......
.......P........PP................P.PPP.P.PP......
..C...........C.......................C...........
...O....O..O....................................O.

Potential for future use:                              x X x
21232323.1323132112.22321.3222113121232232332..20. 0 1 2 3
                                                   1102013
```

Open Responses:

I have personally used:

03:PLATO (PLM files), BASIC programming, Chemistry (Alkene, Alkane - `Smith.)
04:HYDROCARBON NOMENCLATURE evaluated for Systems personnel.
07:Milliken Math Sequences
08:Written own. This is an area I am working on.
15:Milliken Math.
16:Merlan - MITOSIS, MEIOSIS; E.M.E. - OSMOSIS, CHEMISTRY, LIGHT WAVES.
17:Very few - and then only ones that I have made up for very specific application.
18:A program on friction.
27:None.
28:Math Series (SRA), IBIS.
34:Stan Smith's Organic Nomenclature.
35:programs we've developed for computing science.
37:APPLE Super Pilot to make own instructional disks.
39:Budgie program from Australia, Chem program from Addison Wesley.
41:Apple Super-Pilot authoring language.
42:See page 7 (Chem nomenclature, Mole concept, Periodic Table review.)
43:Aerobic Respiration, Nutrition.
46:CELL DIVISION, MENDELIAN INHERITANCE.

I would use if available:

04:Organic nomenclature, mole concept, solutions, etc.
18:Anything of good quality.
21:in all areas where repetitive practice helps - balancing equations, refraction, circuits. Often wherever a formula expresses a relationship.
24:as indicated above. Can be used in most areas of science

teaching.
27:suitable programs for remedial purposes.
28:If suitable and well prepared.
33:computer & software.
35:any good tutorials for chemistry, most are drill & practise.

Other comments:
01:Especially at grade 7 level.
02:The process approach we use does not lend itself to this type of science instruction.
04:Anticipated use for Chem 20 practice with nomenclature but found weaknesses in that iso-, neo-, and outdated usage was included. I liked the generation of isomers. Great concept! I can see myself in a different role if this aspect of usage catches on but I cannot envisage 30 or so terminals per classroom due to cost involved in obtaining and maintaining equipment required.
13:See before the references to "PLATO-type" diskettes - probably the most exciting thing I've seen for micros!
14:The programs I have seen so far are dreadfully boring because the computer has to go to the disk to fetch new problems. With larger memories in computers in future, there might be some possibilities here, but the micros at present are too slow.
17:At the present time, I don't anticipate much use in this area. The software that is available is, for the most part, inappropriate and to write it myself takes too long.
18:Students seem to get impatient and bored easily - although this is definitely a function of the program quality. To keep it interesting, etc., is a very challenging task for the programmer.
22:In spite of the fact that some good programs are now coming out, the limitations of the access to computers greatly hinders this application.
24:Requires a sophisticated program with much branching. Not good software available yet.
28:No suitable tutorial programs at the elementary level at this time - will have limited use.
34:Too expensive - need several rooms full of computers.
35:Good tutorials could be used for remedial work, absent students, or review purposes. Since they are difficult to write, there are few good programs available.
38:I have made a small program but I have not used it as computers are not available for the science class.
40:Do they (Software or Programs) exist?
41:Time consuming to develop a system satisfactory and completed.
44:I have prepared remedial work in physics topics to be used by students.

Gaming:

```
Teacher Identifier:
00000000011111111112222222222333333333344444444445
12345678901234567890123456789012345678901234567890

Degree of experience:                                X x
011130000..1.020010010000102022100120040000100000. 0 1 2 3 4
                                                   2910 5 1 1
Type of experience:
..UUU..U.U....U..U..U.....UU.UUU..UU.UU....U......
.......D.................D.............D....D.....
.......P.................P.............P..........
..C........C..C........................C..........
........O.......................................O.

Potential for future use:                             X x
.1112321.232.121020.21311211121210110322010.2..10. 0 1 2 3
                                                   71813 4
```

Open Responses:

I have personally used:
02:LUNAR LANDER, ARTILLERY
03:PLATO - English programs such as HANGMAN, Nuclear Reactor.
04:Assorted word games and graphics games such as BRICKOUT.
05:ODELL LAKE (species of fish in a lake - food web chain.)
08:Self written.
10:copied disks, sources unknown but Trajectories, Battleship, etc.
17:None. (I have played with a few but am not very enthusiastic about this).
18:Trajectory program.
21:Learn to type games.
27:None.
31:MECC - (Math)
35:A titration and naming of elements based on time.
39:Can't remember title.
44:Commodore user file games (eg: Snoopy Math.)

I would use if available:
10:Chess.
11:A game on Pollution or Environmental Management.
18:Anything of good quality.
21:Almost anything that presents this process well.
27:in the fields to motivate students.
28:It would depend on the degree of gaming and the content.
31:am not aware of enough quality material.
36:Merlin materials.
38:Anything.

Other comments:
04:Used to illustrate computer possibilities in Science 21.

Video arcades and home computers do an excellent job but it's possible that some programs may be classroom adaptable.

13:I dislike the notion of winning in a computer lesson - one of the worst I have seen (sorry - title is gone!) involved a math routine, the object of which was to answer a variety of questions and so "shoot down" the monster descending upon you. The group to which this was being demonstrated had an interesting reaction: they made deliberate errors to see what would happen when the "monster" got you!

15:There are certain typing programs like MASTER TYPE which use this format.

22:(See above, (tutorial).)

24:Probably would only teach small concepts at a time. Good for general science classes.

26:I have 2 programs published in BASIC.

28:Most programs of this nature over emphasize the gaming at the expense of the content.

30:Games packages have some value when introducing students to current software capabilities. ... file handling will be considered for student use & an introduction to them working & writing their own.

33:I don't think this is a good use of computer given the limited time to cover course content.

44:Prepared several game/remedial programs to assist my son in junior high math, spelling, and language arts.

Drill-and-Practice:

```
Teacher Identifier:
00000000011111111112222222222333333333344444444445
12345678901234567890123456789012345678901234567890

Degree of experience:                                  x X x
00203012211110211100.00001111211001130433112004002 0 1 2 3 4
                                                  1818 7 4 2
Type of experience:
..U.U.UUUU..U.UUUU.......UUU.UUU..UUUUUUU.UU..U...
.......D.D...............D..........DDD.D..D..D...
..P....P.PP.P............P..P.....P.PPP.P..P..P...
..C......C.C..C.......................C...........
................................................O.

Potential for future use:                                x X x
1123232222.2212.113..112213332223031.33332222.310. 0 1 2 3
                                                   2101813
```

Open Responses:

I have personally used:

03:Ionic nomenclature program, PLATO Chemistry, Organic Chemistry (Stan Smith.)
05:Milliken Math.
06:MECC Teacher Utility
07:Milliken Math Sequences.
08:Self written, SERAPHIM disks.
09:Cannot recall programs.
10:Basic programming skills to encourage students to program their own program to solve a variety of math problems.
11:Drill and Practise Program developed for EdInd496.
15:Milliken Math.
16:E.M.E. - CHEMISTRY, CHEMICAL SYMBOLS.
17:A number of MECC mathematics packages (Equations, etc.)
18:Trajectory problems, constant accel. problems.
27:Nomenclature, optics - locating position of an image in mirrors & lenses.
28:Math programs.
29:A chem elements & symbols prog that I wrote.
31:PLATO - Mechanics
35:several by Paul Cauchon that students have typed in and I have modified.
36:Merlin software.
37:Miliken, APPLE Super Pilot.
39:Author developed programs, drill on Chem Naming (Addison Wesley.)
40:Chemical Nomenclature Organic and Inorganic.
41:Home-made-tailored to student requirements.
42:See page 7 (Chem nomenclature, Mole concept, Periodic table review.)
43:Chem drill.
47:Chemical Nomenclature (inorganic and organic.)

50:Milliken.

<u>I would use if available</u>:
04:Stoichiometry.
11:Milliken Math.
18:Anything.
24:Has many applications especially for material to be "memorized".
27:in the respective fields.
28:If it matches the curriculum I would use it.
33:computers & software.
35:programs which randomly generate questions in chemistry.
38:Anything.

<u>Other comments</u>:
01:Periodic Table
04:Useful possibility for students requiring remedial practise.
06:Questions for the drill-practice program file in the program are entered by the teacher.
09:I would not use drill and practise in my areas as much as I would like to see it used in Math 15, 25, and 13 programs.
11:Students who experienced some difficulty with basic operations of whole numbers showed considerable improvement when placed on computers two or three sessions. This was limited by the short period of time in which a computer was available to my class.
13:Again, the majority I have seen are very poor.
14:Anything I have seen so far in this area has been supremely boring and does little the pencil and paper does not do more efficiently.
17:This has some definite benefits although I am not aware of many programs that would fit into the subject/grade levels at which I need them.
18:Again, kids seem to be quickly bored with this.
21:Sub concept of `tutorial'? See p.9. This is going to be extremely valuable for individualizing instruction.
22:(See comments above, (tutorial.)
28:Good for remediation.
30:I can see the use from my experience in Edmonton at the Clearing House for Mathematics.
35:We've recently bought an Apple in our department and have built a cart with a large screen so that it can be used in individual classrooms. We plan to use programs for the above.
44:See comment on previous page. (Prepared several game/remedial programs to assist my son in junior high math, spelling, and language arts.
47:Have written drill & practice programs for Chem 10 course.

Electronic Chalkboard/Calculator:

```
Teacher Identifier:
00000000011111111112222222222333333333344444444445
12345678901234567890123456789012345678901234567890

Degree of experience:                                X x
00000001010012013200010001010300101010200000000100. 0 1 2 3 4
                                                   3311 3 2 0
Type of experience:
.......U....U..UU....U...UUU.U.UU.U.UUU.......U...
.......D.....D.D.....D............................
.......P.P...P.PPP................P...............
......................................C.........C.
........O..O......................................

Potential for future use:                               x X
2.112322..31.33222..322112312.00303113212.0.1.211. 0 1 2 3
                                                    41214 9
```

Open Responses:

I have personally used:
08:Self written.
10:Sound, graphics, motion graphics to demonstrate types of programs which students could design.
13:Titles gone!
14:Geometry of refraction.
16:This method as a chalkboard application - student notes and example.
17:Polygraph (MECC) as well as specific home made programs.
18:Home made pgms on plotting functions (quadratics) and comparing results.
22:various noncommercial programs.
27:None.
35:will use programs that we have & ones that we've ordered.
37:A multimedia video disk system.
39:Miliken Oil droplet.
47:Graphs.

I would use if available:
18:Anything of good quality.
27:in the school.
28:It would have limited use at an elementary level.
30:... Plot; Graphing Package.
33:computer & software.
35:Several commercial programs that are recently available.
38:Anything.

Other comments:
01:Saves use of blackboard-better than overhead.
03:Perhaps with a word-processor.
04:Not too many mobile computers available for classroom use. What, no more overhead? This would be a Xerox

replacement but reading the print from a screen would not improve student negative response towards printed information but may force them to read before they can proceed.

13:Again, I would not like to see a computer replace a child looking through a microscope - at least at this time.

14:This area is within the potential of the present micro and teachers should organize to get more activity generating programs, sharing programs, and ideas in design and use of sub-programs.

17:For my Math 31 class, this is an important application. We often explore more complicated problems because of this. I have found that the micro has added an important dimension to this course in particular.

18:Find the animated displays, and computational aids to be most useful. Taking notes from a monitor is a pain and generates eyestrain.

21:A "smart" overhead? Great! But: Requires a large screen technology for in-class work.

22:This is closely related to other areas in which I am both interested and active in. I intend to do more in the future.

24:Don't really appreciate this use as I haven't seen programs and have doubts of its efficiency.

29:I don't have a computer to use in my classroom.

30:Plotting functions in Math 31 - graphing sections max & min.

35:Stan Smith is the author of several chemistry programs available for PLATO and APPLE that are excellent.

37:Really neat but far too expensive for classroom use.

47:Used to illustrate effective of changing variables in trig equations and conics.

Laboratory Instrumentation:

```
Teacher Identifier:
00000000011111111112222222222333333333344444444445
12345678901234567890123456789012345678901234567890

Degree of experience:                                 X
0000000010001000100000000011002100001200000000100. 0 1 2 3 4
                                                  39 8 2 0 0
Type of experience:
........U...U..............U...UU...UUU.......U...
...........................D...D....DD............
................P...................P.............
..................................................
..........O.....................................O.

Potential for future use:                            x X x
121213211030.23133..22201023130.33230312.21.2.2.0. 0 1 2 3
                                                   7101311
```

Open Responses:

I have personally used:
17:Some simple graphing or lab analysis programs (home made). Other than that, nothing.
22:(For analysis and display) - my own material plus colleagues'.
27:Titration, Energy calculation.
36:Merlin Software.
37:APL and other direct on-line data input/analysis - university undergrad teaching and research programs.

I would use if available:
17:There are a good number of timer, frequency counter, etc., interfaces that would be of very real benefit in the Physics lab.
18:Anything of good quality.
19:THE TEACHER'S MARKSHEET by Harvey Brown - Apple II or IIE (c) 1982 by Spirit River S.D. #47.
27:in the school.
33:computer & software.
34:Connection to a photometer for checking concentrations. Connection to a pH meter for display.
35:programs for pH meter, spectrophotometer, if APPLE compatible.
38:Anything.

Other comments:
01;Hopefully in future.
04:Useful possibility if programs available for this purpose. University and NAIT labs will probably get into this aspect before high school labs do so. Instrumentation fairly limited in high school.
09:I have used this type of program at university, however

software for the classroom, at least for my part, is not available as far as I know.

13:Again, in Physics I have seen routines which allow analysis of an experiment on an air track (accelerated motion, say) - I feel the initial hands-on lab experience to be superior to a computer analysis. However, I should like to see routines in the other sciences so that I may then frame an opinion.

14:This seems an exciting area but may prove to be too complex to come into widespread use by all teachers. My hobby and interest is electronics, yet the complexity gives me difficulties.

17:I see this as a very important role for the microcomputer and an area that I look forward to with excitement. At the present time, such interfacing still seems quite expensive which is a drawback for our school.

18:Sounds great ... but expensive!

22:NB. Rate = 0 for interfaces, Rate = 3 for analysis and display. Except for the remote sensing aspect, I have been using computers for many years to analyze and display lab results either for my marking or for students checking (verification). I intend to do more in this area in the future.

24:Very expensive. Most labs at the high school level do not need the sophistication available with computers. Most labs are qualitative rather than quantitative.

26:Time constraints prevent my going into this much as a designer; budget constraints prevent purchase.

28:This would have greater application as the grade level increased.

30:We have not used any of the above in my classroom. But I have & do some work at the U of C on writing & building interfaces for a 8095 CPU. I like the idea but it is very time consuming.

35:One of the problems we've encountered is that no one seems to know anything about interfaces for lab equipment. Eventually I hope this will be rectified.

Other Phase II Activities/Comments:

```
Teacher Identifier:
00000000011111111112222222222333333333344444444445
12345678901234567890123456789012345678901234567890

Degree of experience:                              X x x
..........0..0....00...0....2......0..33..0.....0. 0 1 2 3 4
                                                   8 0 1 2 0
Type of experience:
............................U.........UU..........
......................................D...........
......................................P...........
............................C.........C...........
................................................O.

Potential for future use:                            x X
2.................1.........3.........22..0.....1. 0 1 2 3
                                                   1 2 3 1
```

Comments:

01:Teaching instrument as above if available for full-time use in the classroom.

04:Graphics programming introduced in Science 21 Computer Literacy module as well as program development on computer usage using as computer.

20:I have not had opportunity to explore the potentials nor my involvement in this area as yet.

22:Classroom simulation and lab applications are the two big areas for me at the present time. I really cannot foresee extensive use of the other areas in the phase in the near future. Other than record keeping, these 2 areas seem to "grab" people the most.

28:There is very little courseware on the market for elementary science. None has yet been approved by the provincial ClearingHouse.

29:I have prepared extensive notes on MAGIC WINDOW (a word processing prog); - with the help of 2 students. We (one student & I) presented a word processing workshop to the English 30 (top) class. I will be giving a workshop to my top Phy 10 class next week (Mar 84.)

34:The simulation part should be broken into two categories;
1. modelling.
2. checking complex calculation.

40:Teaching Word-Pro and Manager Data Systems to Small #s of students in Special Projects (Work Exp.)

Phase III:

Test Production:

```
Teacher Identifier:
00000000011111111112222222222333333333344444444445
12345678901234567890123456789012345678901234567890

Degree of experience:                               x x X x
22431113300000214020230102023230043320321221331301 0 1 2 3 4
                                                  14 91212 3
Type of experience:
UUU.UU.UU.....UUU.U.UU.U.UUU.UUU.UUUUUU.UUU.UUUU..
....D..D......DD.....D...........D.DDD.D...D...D..
.P..P..P.......P.....P...P.......PP.PP.....P......
..C...........C......C...........C....C...........
...O.......OO....................................O.

Potential for future use:                                x X
3333..3330332232313.23332233322233.3232.3332333.1. 0 1 2 3
                                                   1 21228
```

Open Response:

I have personally used:

01:APPLE WRITER
02:MAGIC WINDOW, BANK STREET WRITER
04:All our Chem exams are retrieved from EPSB item bank.
05:Have seen and used IBIS at a workshop. Have tried very simple questions.
06:MECC Teacher Utilities - Test Generator
07:I have used the MECC Utilities #1 diskette to prepare a couple of tests this year.
08:DBMS, Word Processor, Self written `generator' program.
09:Teacher Utility from MECC.
14:SUPER-TEXT.
15:My own materials created on a word processor as well as a Koala Pad or Graphics Tablet.
16:I.B.I.S. - Dr. Petryk's program.
17:SUPER TEXT.
19:TEACHER UTILITY, M.E.C.C.
21:EPSD Item banks.
22:various word processors & my own programs.
24:CUE-MATH from Calgary Public.
26:VIP WRITER; QUIZMASTER (for CoCo); my own programs.
27:None.
28:APPLE WRITER II(E) and the MECC - Test Generator.
29:a and i (above) [manual storage and retrieval of test material.]
31:APPLE WRITER, HOMEWORD, BANK STREET WRITER.
34:Super-Text and Gutenberg word-processing programs.
35:Word Processing and programs designed by others for multiple choice and problem generators.
37:APPLE WRITER, BANK STREET WRITER, SUPER PILOT to prepare

tests and notes.
39:CML System, CLAS, DATA FACTORY, MAGIC WINDOW II.
40:Use of Word Pro for my own exam construction, storage, and retrieval. Calgary Public is working on this area for sciences.
41:CML System (Calgary Board's)
42:CML - Calgary Board of Ed - Prog. Evaluation Dept - Test item banks.
43:Word processor.
45:Olympia Word Processor and Apple IIe - Word Juggler.
47:a) [store and retrieve] and i) [visual search and revise] above, personally with PFS and Applewriter and Central EPSB services.
48:Apple Writer, Creat a Test.

<u>I would use if available</u>:
09:Any program which will enable the incorporation of diagrams.
21:anything that I could trust - i.e. - well revised items +/or templates.
22:a combination data base/word processor for objective-based test items.
24:Test banks in Chem., Bio. as they become available (soon) from Calgary Public.
26:others of this type on disc.
27:feasibility is in the school system.
29:I could find the time item b (above) [generation using template.]
33:computer & software.
43:random selection of items.
48:Data base.

<u>Other comments</u>:
01:Would use frequently.
02:Can create test banks. This usage encourages modification of `faulty' test items with minimal effort.
03:Use computer as a word processor for test construction. I think this is a very important (most important?) use of computers in schools today. Would be good if a single school could develop a bank themselves. Questions are better [than full tests.]
04:Easiest to sell and use but costly to produce.
09:In Chemistry, problem arises with use of capitals and subscripts. Have used computer extensively in physics.
14:Who will organize such a question bank? The only realistic way for this sort of use is a central source that puts items on disk or a large central computer and modem arrangement to download items.
17:A boon! I use the word processor a great deal to prepare tests, quiz - to keep a bank of project topics, etc. (My students are starting to use word processors as well.) It is very useful to give pretest - posttest, and retests - something I was less willing to do before using the word processor.

18:Most of these I have seen tend to be identical questions - but different numbers. A drag for many students.
20:Consider using Gutenberg in test item compilation. (Future prospect.)
26:Really made my job easier here. I have a databank of about 200 (?) questions in G8 Science.
28:This will enable banks of valid questions on topics to be developed.
29:Almost all my tests are stored on word processor disks. I don't use item banks.
30:The use of CUE Math on the Deck Writer. A test bank of questions provided by the Public School Board.
31:Secretary puts all my current tests, outlines, on Commodore & IBM files. I personally use APPLE WRITERs.
34:We have two years x 1/2 day secretary worth of tests on file for use. Many are run on ditto stencils produced by the computer printer. Revising tests and creating parallel forms (with new numbers in the problems) is important to increasing the quality of evaluation.
35:I would like to see test banks available for ALCHEM, biology & physics. Right now I'm doing my own input of questions but it is a waste of time. School boards or the Dept. of Ed. need to collect, organize and develop test banks, problem generators, etc.
38:I am in the process of obtaining a program to use as test item bank - maybe Quickfile IIe.
44:See comments on page 9. [Tutorial and Gaming.]
45:A great way to do tests - can change them easily.

Test Scoring:

```
Teacher Identifier:
00000000011111111112222222222333333333344444444445
12345678901234567890123456789012345678901234567890

Degree of experience:                                X x
00023000000000011000001000102030000112011001200100. 0 1 2 3 4
                                                   3310 4 2 0
Type of experience:
....U.........UU.....U...UUU.UUU..UUUUUU..UU..U...
...............D....................DD............
.........................P..........PP............
....C.........C...................................
...O....O...O...O...............................O.

Potential for future use:                                X x
3222333021323232.232.2022.3322.2302.231231122.321. 0 1 2 3
                                                   3 52114
```

Open Responses:

I have personally used:

04:Periodically, our exams are sent to EPSB for analysis.
05:(Name unknown) program came on a disk and is used with the card reader.
16:I.B.I.S.
22:EPSB services.
27:None.
28:MECC Test Generator for on screen review only.
30:Marks program.
35:Have access to programs that need to be refined for our purposes.
37:Chatsworth Data program, Super Pilot.
43:Test Scoring.
44:Calgary Brd of Ed. system wide exams at grade 12.

I would use if available:

18:Anything of good quality.
24:in much of my testing.
27:software and card reader are available.
28:Yes for part of my testing.
29:A mul choice scoring machine and test analysis program.
33:computer & software.
35:Short quizzes for individualization purposes where computer marks the student as he does the quiz. We've developed a couple for computing science on an experimental basis.

Other comments:

01:Save marking time
04:Available through EPSB but how many teachers use it?
09:Optical reader or student input of responses could be accomplished, however if only 1 terminal is available, it

is time consuming.

14:To give a test on computer would require a large number of terminals for which we do not see the budget or physical space in the near future. The organization problems also seem very large.

15:Due to lack of appropriate software and inadequate automated system, this is not being used like it could be.

20:This is something I am considering.

24:Great to have individual tests for each student. Could give tests as student finishes concepts. Easier testing of students absent for normal test sitting.

26:I hate to lock my computer up with one student. Poor use of a limited resource.

30:The school has an optical marker for multiple choice questions.

31:Scoring machine is presently being installed.

38:I am making tests which I will use.

40:Only as a subject in field testing for exam items that will eventually be available to all Calgary Teachers.

Test Records and Determination of Course Marks:

```
Teacher Identifier:
00000000011111111112222222222333333333344444444445
12345678901234567890123456789012345678901234567890

Degree of experience:                                  x x x
43443133310130410401243132233330232110143200043301 0 1 2 3 4
                                                  1010 616 8
Type of experience:
UUUUUUUUUU....UU.U.UUU.UUUU...UUUUUUUUUUUU....UU..
D.D....D......D......D.......D.........D.......D..
P.P.P.PP....P........PP....P.................PP...
CCC.C.C....C..C.....CC...........C................
................................................O.

Potential for future use:                                x
33333333313332.2.333.332.2.33333333.13133331233.0. 0 1 2 3
                                                   1 4 532
```

Open Responses:

I have personally used:

01:MARK MAINTENANCE
02:CLASS RECORDS (Alphatel)
03:Author of CLASS RECORDS (and future versions.)
04:ALPHATEL Marks Records.
05:Alphatel - Marks Master.
06:ROSTER
07:a) Alphatel "APPLE MANAGER" and
   b) "THE CLASS MANAGER" (Merlan Scientific Ltd.)
08:VISICALC, Self authored.
09:Marksheet locally and from Grande Prairie, same Marksheet. And Gov't result program.
10:GRADE BOOK.
15:VISICALC, CLASS RECORDS, and some home made programs.
16:Merlan - CLASSROOM MANAGER.
18:"CLASS RECORDS" - Mike Falk.
20:CLASS RECORDS (Alphatel)
21:CLASS RECORDS
22:a "wonderful, highly-acclaimed" product - CLASS RECORDS.
23:personal "GRADES PROGRAM" revised from Public Domain Program.
24:a marks manager.
25:Alphatel.
26:Tom Mix's TDB (for CoCo.)
27:VISICALC, CLASS RECORD.
28:My own program.
29:Alphatel CLASS RECORDS.
31:COMPU MARKS, CLASS RECORDS, MULTIPLAN, VISICALC.
33:Name unknown or locally produced - I've used several for Apple & IBM.
34:Falk/van Kessel Grades Program.
35:Student-developed program for PET and the APPLE program.

Both are adequate for my use.
37:I have evaluated several programs with this feature.
38:CLASS RECORDS - MARKSHEET, VISICALC.
39:SRA Math.
40:Manager Data Base for CBM 8032 which we modify for the construction of student reports on a local basis within the science dept.
41:CML Records System.
42:COMPUMARK and SAITS' RECORDS
47:Class Manager.
48:Visicalc.

I would use if available:
09:any program which would be easily accessible and useable.
24:a marks manager.
27:in this field.
28:Yes.
33:computer & software.

Other comments:
01:Record of class marks; year and term marks, using now.
04:This program was locally generated and available. Already exists, easy to use, cheap and effective.
07:I have modified the "Class Manager" to suit the needs of [School]'s teachers.
09:Implementing HARTS III to monitor marks, print Alta Results statements, and teacher's markbook.
15:This is an excellent mechanism for introducing teachers to the computer. It is best to start with a menu-driven program and then advance to more complex programs like VISICALC.
18:An excellent use for computers. Allows many options too tedious when marks were computed using pencil and paper.
21:Very desireable from classroom teacher's point of view.
22:This seems to be a popular item and I am in the process of expanding computer use in this area.
23:I keep all my marks by Apple computers.
24:Works well.
26:No time saving but I like the print-outs. I give my science clases a report every 2-3 weeks - very motivating.
28:A computer managed system has potential so long as the teacher chooses the activities and not the computer.
29:[A teacher] and I conducted a teacher workshop on the use of Alphatel CLASS RECORDS (and on word processing) last year. I have conducted such a workshop this year by myself (since Fred has left).
30:I have been keeping marks on a computer for the last 6 years. I have not use a computer managed system.
34:Printing of marks is my only experience - the students like it.
47:Conducted inservice for teachers on how to use the computer for determining marks.

Test Item Analysis:

```
Teacher Identifier:
00000000011111111112222222222333333333344444444445
12345678901234567890123456789012345678901234567890

Degree of experience:                              X x
0002300000000010.1001201000001.000002031001204010. 0 1 2 3 4
                                                  32 8 4 2 1
Type of experience:
....U...U.....U..U..UU.U..UU.U.U....UUUU..UU.U.U..
....................................D..........D..
....................................P.............
....C.............................................
...O.......O....................................O.

Potential for future use:                            x X x
2222333111323230.23.2212113322.1211.23233.1123.21. 0 1 2 3
                                                   1121713
```

Open Responses:

I have personally used:
05:Program used with card reader.
15:The mainframe at E.P.S.B.
24:a marks manager.
27:None.
37:Chatsworth Scoring Program.
39:C.B.E. Program
44:C.B.E. system wide exams.
46:Edmonton Public Schools test service.
48:Visicalc.

I would use if available:
09:any program that would accomplish this.
15:an appropriate software program designed for the Apple IIe.
18:Some general analyses which could be customized to my own specific needs.
22:EPSB services.
24:a marks manager.
27:in the field, the required technology.
33:computer & software.
34:Standard error of measurement (the uncertainty of a report card mark) is what I would like.
38:Anything.

Other comments:
01:Would help eliminate bad questions.
04:Available through EPSB.
05:Most of these questions are from C.R.I.B. I believe there was no formal test item analysis but most of the questionns have stood the "test" of time?
09:used only on multiple choice items so far have been done

by hand.
14:This will be useful but it will have little impact on the nature of learning. It may be detrimental in that it will encourage exclusive use of multiple choice as the method of evaluating students.
21:Have done this with EPSD + Alberta Ed.
22:I would be using this & test scoring if I had the equipment & the time.
24:The statistics obtained are very important and are not usually done for ordinary tests without the computer.
28:This would be very handy and certainly would enable better test construction.
30:Currently I am writing written questions for the Public School Board which will all be subjected to stats.
31:As mentioned, scoring machine is being installed.
34:The facility to qualitatively analyze your test and revise it on the word processor is a far more important advantage.
40:Only from both Work in Calgary for our eventual use and Exam construction in both Calgary and Edmonton exam const.
41:CML System may at some future point make this information available.

Correlation of Marks and Analysis of Trends:

```
Teacher Identifier:
00000000011111111112222222222333333333344444444445
12345678901234567890123456789012345678901234567890

Degree of experience:                              X
0100000001001010.00000010000000000000001000000110. 0 1 2 3 4
                                                  40 8 0 0 0
Type of experience:
.........U....U........U..U...UU.....U.U......UU..
...............................................D..
............P.....................................
..................................................
........O..O....................................O.

Potential for future use:                            x X
.222.32001322130.1...21.113..2.12.1..3.32.1.1.120. 0 1 2 3
                                                   41111 6
```

Open Responses:

I have personally used:
02:CLASS RECORDS (Alphatel.)
10:GRADE BOOK, also a program developed by Spirit River.
15:VISICALC.
24:a marks manager.
27:None.
48:Visicalc.

I would use if available:
27:technology and software are available.
33:computer & software.
38:Anything.

Other comments:
22:(See above (test item analysis.)
24:Obtain more statistics so a person can track students, tests, classes, or items.
28:Again has potential but must not become the dominant factor in educational decisions.
29:[`?' written next to `longitudinal'.]
30:The program would have to be efficient before I would use them because of the time available.
40:A service that was worked on in our city-wide exams. It was good! But since the advent of Alb. exams, the dev. has been replaced by an insidious large farce with no goals or logical benefit to students or teachers.
47:Placement of marks on a division wide basis for statistical purposes, Mean, S.D., etc.

Career Guidance:

```
Teacher Identifier:
00000000011111111112222222222333333333344444444445
12345678901234567890123456789012345678901234567890

Degree of experience:                               X x
0010000010000020.10000011110001000100031..0000120. 0 1 2 3 4
                                                3211 2 1 0
Type of experience:
..U.....U.....U..U......UUU...UU..U..UUU......UU..
..................................................
..................................................
..C...........C................................C..
...........O....................................O.

Potential for future use:                             X x
.111.3003031.23..1...11...1.110.2.1..121..1.1.112. 0 1 2 3
                                                   417 4 4
```

Open Responses:

I have personally used:
03:PLATO offers some career counselling.
04:Counselling uses CHOICES extensively but how effectively I don't know.
15:The CHOICES terminal.
18:"CHOICES".
25:CHOICES.
26:CHOICES.
27:CHOICES.
31:CAREER FACTORY.
39:CAREER FACTORY.
42:CHOICES - have viewed this program through our guidance dept.
47:CHOICES.
48:CAREER FACTORY.

I would use if available:
15:Software packages usable on an Apple IIe computer.
27:In a better format.
33:computer & software.

Other comments:
04:I may not use it in my own classes but its use may exceed mine in counselling area.
09:Presently, the counsellor in process of obtaining careers choices on computer. I do not know name of program.
22:This would be a good application since it is an area generally neglected in the schools. Every school should have this computerized capability.
24:We have a career factory in the guidance area. Is well used.
28:Not relevant to elementary.

29:We have a "CHOICES" program in the guidance dept at [our school.].
35:Our guidance department regulates the use of CHOICES in our school.
38:This is not my area of instruction at present.
40:We have CHOICES.
41:"Career factory" is used in our school by the guidance department.
47:Excellent program.
49:To build an interest in Science.

Other Phase III Activities/Comments:

```
Teacher Identifier:
00000000011111111112222222222333333333344444444445
12345678901234567890123456789012345678901234567890

Degree of experience:                              X
..........0..0....0....0..........00............0. 0 1 2 3 4
                                                   7 0 0 0 0
Type of experience:
..................................................
..................................................
..................................................
..................................................
................................................O.

Potential for future use:                            x X x
..........3.....................................1. 0 1 2 3
                                                   0 1 0 1
```

Comments:

01:If available for full time use in a classroom, it would be used for - teaching, scoring, recording, and test production. Because of limited availability, it is not being used to its fullest potential.

04:This area will probably hit the schools before the previous two categories become a reality in that most teachers have used the services available. Ideally, item banks should be available and accessed via terminal in the schools from which hard copies can be obtained and Xeroxed but even this usage is not yet a reality to the extent that is should be. The Alphatel Marks Record is extensively used by myself but I cannot imagine the same type of input into curriculum software unless Alberta Ed. is prepared to hire a team of programmers to generate the tremendous numbers of test questions or concept areas needed for computers to assist educators with instruction. Might be a reality when Peter and Dave recognize that education is costly and that computers could improve the end product. In general, future uses are all possible but cost would prevent certain usage, e.g., World Book Encyclopedia already exists but, at $15 to $25/h, a $350 set would go a long way in achieving the same results not counting the cost of terminals and hardware required to access World Book. Phones exist but how many times does one talk to people when long distance tolls are considered? Computer use would cost a great deal more than long distance tolls. What bothers me about computer usage questionnaires is the "pie-in-the-sky" type of approach rather than trying to analyze current problems, applications, or extended and effective use from "where-we're-at" rather than "where-we-might-be" approach.

05:As more people and schools become involved in computers -

buying and using hardware then courseware (software) - the cost of material and maintenance will become more of a factor of implementing programs and the use. Maintenance can be incorporated into budgets but I think if there is no effort for more sort of information sharing or shared information retrieval, cost will limit the use of computers in most school.

08:Most of my IBM software is Self Authored.

11:The possibilities for computer use in the classroom are staggering! However, the key to the problem is to get computers into classrooms rather than having them isolated in a computer room for computer literacy classes. I suppose once the "computer lit" fad dies down a bit, computers may move into the classroom where they can be of real "practical" benefit!

15:In all areas of computers, materials could be created which would be an invaluable asset to teachers and educators. The biggest problem in this field is piracy which is preventing quality programs from being developed. The current monetary situation is also not conducive to expansion of these ideas at this time.

17:After reading the past 5 items, I can see that they could be very useful but when does the classroom teacher find time to do this? My only experience in this last section comes through the simple management of test/class grades. Our Marks Management System does have the statistical packages needed to do the above analysis but I have not used them.

20:Sorry not to be of more help, but I have not yet assessed the potential of computers in my teaching. In due course, circumstances permitting, I do hope to involve computers in some aspects of my teaching. Prospects may be more conducive and encouraging in the future? Available time is my shortcoming, as it must be with most people contemplating some use of computers in their teaching.

21:Major flaw is incredible lack of "time to play." There are dozens of applications - but I can't see much happening in school, except where you have a teacher-fanatic present (the [innovator's name] syndrome.) Any ideas?

29:There seems to be many areas I know nothing about.

33:I will generally use the response "budget & suitable computer" or "computer & software" here because computers are under Business Education and not generally available to Physics classes. Physics class has 5 Sinclair ZX81 with 16K RAM and all programs are written by me & students I've trained as an extracurricular project.

34:Evaluation of my tests and curriculum materials within the classroom setting and the subsequent improvement of these materials is NUMBER 1 on my list. Five or ten year-old junk has no place in the classroom of the future. This is the most important use of computers in education.

Old tests can be re-newed by adding contexts (e.g., Nature of Science; Science and Technology, or Science and Society) to otherwise sterile test questions.
I have not included my limited PLATO experiences (learning BASIC) in this response.

35:Here are a few comments or problem areas in the use of computers in science education.

1. The reluctance of teachers to become literate and to use the computer. We have an APPLE IIe in our department that is used by myself & a few students.
2. Most of the chemistry courseware previewed by Dept. of Ed. has been rejected but in the last year the publishing companies have been producing much better quality courseware.
3. The cost of courseware is too high for most schools to invest in large quantities.
4. I see a real problem with teachers developing expertise to learn about interfacing lab equipment, etc., as well as having the time to develop their own specific courseware or to change the existing courseware.
5. The use of poor courseware just because it is there. For instance there are several laboratory simulations that can be done in the laboratory. Also there are programs available for balancing equations on the computer. Many uses are not justifiable.
6. I have not seen many tutorials, never mind quality tutorials with provisional branches for individualized instruction.

38:I use SCREENWRITER to make up all the materials for my classes - tests, information sheets, etc.

44:Using Paper-clip, I have a data bank of multiple choice questions which I will be using in June to prepare review sheets. My present involvement is in writing programs to deal with problems for self interest or to be used by specific teachers - I am still busy trying to convince my colleagues.

49:For 10 years, I have been waiting for suitable programs (software) in Mathematics, Language, and Science. I do feel that in the Elementary school, it's main use and greatest value will be in Computer-Assisted-Instruction for high, average, and low students. Its use in C.A.I. should lead to much more individualized instruction.
As you will see by my answers, its use, in a good, activity ("hands-on") science program in the elementary school, will be limited to providing `back-up' services and `extension' work (in what I feel will be rather limited units of study.)
But, let us get the software and try the programs.

Appendix C

Computer Programs Used by Teachers Who Responded to the Questionnaire on Computer Uses

Programs Used by Teachers in Study
(From Responses of Teachers on Questionnaire)
(N = 50)

Program Type and Name (and Source)	Use of Computer in Science Teaching: Phase I					Phase II							Phase III					
	P	D	C	L	M	P	S	T	G	D	C	L	P	S	R	A	T	G
__Authoring__																		
CLAS System	X												X					
LOGO Language						X												
SuperPILOT Language					X			X		X			X	X				
__Career Information__																		
Career Factory																		X
CHOICES																		X
PLATO Careers																		X
__Communication__																		
ASCII Express		X																
Electronic Mail			X															
ENVOY (Altel Data)		X																
Novation Com-Ware		X																
VisiTerm (Visicorp)		X																
__Data Based System__																		
D.B.Master			X															
Data Factory				X									X					
E.R.I.C.				X														
File Cabinet	X																	
I.E.P. Manager	X																	
Manager													X					
PFS: File	X			X														
PFS: Report	X																	
__Graphics Utility__																		
ApplePlot	X																	
Graphics Tablet													X					
PolyGraph (MECC)											X							
__Instructional Management__																		
C.M.L. (Calgary)					X													
CHATAUQUA					X													
H.A.R.T.S. III					X													
MarkSheet (Alta.Ed.)					X										X			
__Inventory Control__																		
D.B.Master					X													
__Optical Mark Reader__																		
Chatsworth Scoring					X									X		X		
SCAN-TRON Data																		

Program Type and Name (and Source)	Use of Computer in Science Teaching																	
	Phase I					Phase II							Phase III					
	P	D	C	L	M	P	S	T	G	D	C	L	P	S	R	A	T	G
Marks Management																		
Class Manager		X													X			
Classroom Manager					X													
Class Master					X													
Class Records			X		X										X		X	
Compu-Mark (Peters)					X										X			
Grade Book (Apple)					X										X		X	
Grades					X													
Mark Maintenance															X			
RECORDS (S.A.I.T.)			X												X			
Roster															X			
TDB (Tom Mix/CoCo)															X			
Teacher's Marksheet															X		X	
SpreadSheet																		
Lotus 1-2-3					X													
MultiPlan				X											X			
VisiCalc	X	X			X		X								X	X	X	
Test Construction																		
CML (Calgary)													X			X		
Create A Test	X												X					
CUE-Math (SAIT)													X					
IBIS (Petruk)	X	X						X		X			X	X				
Teacher Utility #1	X	X								X			X	X				
QuizMaster (CoCo)													X					
Test Services (Edm)	X												X	X		X		
Word Processing																		
Apple Writer	X												X					
Apple Writer IIe	X												X					
Bank Street Writer	X					X							X					
Gutenberg	X	X	X										X					
Gutenberg Jr.	X																	
HomeWord													X					
Juggler IIe	X																	
LexiChek	X																	
Magic Window	X												X					
Magic Window II	X												X					
Olympia													X					
PaperClip	X				X								X					
PFS: Write	X																	
Screen Writer	X												X					
ScreenWriter II	X																	
Super-Text (Muse)	X			X									X					
VIP Writer													X					
Word Juggler													X					
WordStar	X																	
WordPro	X																	
WordPro 4		X																
WordPro 64		X																

Program Source and Name (and Source)	Use of Computer in Science Teaching																	
	Phase I					Phase II							Phase III					
	P	D	C	L	M	P	S	T	G	D	C	L	P	S	R	A	T	G
COMPress																		
Alkanes & Alkenes								X										
Educational Materials and Equipment																		
"A" Machine							X											
Chemical Symbols										X								
Chemistry								X		X								
Inclined Plane							X											
Light Waves							X	X										
Osmosis								X										
Thinking & Learning							X											
M.E.C.C. (ACCESS)																		
Collisions in One Dimension							X											
Heat Loss							X											
Millikan Oil Drop							X				X							
Odell						X	X		X									
Optics						X												
Solubility Product						X												
Titration							X											
Volcanoes						X												
Merlan																		
Meiosis								X										
Mitosis								X										
PLATO																		
BASIC (PLM Series)					X			X										
Chemistry	X									X								
Elementary Physics	X							X										
Estimation	X							X										
Fraction	X							X										
Hangman									X									
Mechanics										X								
Nuclear Power Plant							X		X									
Science		X																
Project SERAPHIM																		
(Unnamed Disks)										X								
WICAT Education Institute																		
Videodisc in Science Education					X													

Subject Content Program Name (Source unknown)	Use of Computer in Science Teaching Phase I					Phase II							Phase III					
	P	D	C	L	M	P	S	T	G	D	C	L	P	S	R	A	T	G
GENERAL SCIENCE																		
Earthquake							X											
BIOLOGY																		
Aerobic Respiration								X										
Bighorn Sheep							X											
Bison							X											
Budgie							X											
Cell Division					X			X										
Ecology							X											
Genetics							X											
Mendelian Inheritance					X			X										
Nutrition								X										
Odessa Lake						X												
Population							X											
Rats							X											
Tribbles							X											
Whale							X											
PHYSICS																		
Air Table							X											
Artillery									X									
Battleship									X									
Conservation of Energy						X	X											
Conservation of Momenteum							X											
Constant Acceleration										X								
Energy Calculation												X						
Geometry of Refraction											X							
Interference of Waves							X											
Lab Analyzer						X												
Lunar Lander									X									
Optics - Images										X								
Orbits of Planets							X											
Projectile Motion							X											
Radioactivity							X											
Rutherford Scattering							X											
Sound Wave Synthesis							X											
Trajectories									X	X								
Vector Addition							X											

Use of Computer in Science Teaching

Subject Content Program Name (Source unknown)	Phase I					Phase II							Phase III					
	P	D	C	L	M	P	S	T	G	D	C	L	P	S	R	A	T	G
CHEMISTRY																		
Chem Naming										X								
Chem Nomenclature						X		X		X								
Gas Laws and Kinetic Molecular Theory	X				X													
Ener-Calc						X	X											
Ionic Nomenclature										X								
Mole Concept						X		X		X								
Naming of Elements									X									
Periodic Table						X		X		X								
Titration							X		X			X						
UNCLASSIFIED																		
Brickout									X									
The Factory						X												
Rocky's Boots						X												
Master Type									X									

Note:

Phase I = Preparation for Teaching
P = Curriculum Planning and Materials Preparation
D = Professional Development
C = Communication between Schools and/or Teachers
L = Library Applications
M = Instructional Management

Phase II = Teaching
P = Problem Solving
S = Simulations
T = Tutorial
G = Gaming
D = Drill and Practice
C = Electronic Chalkboard
L = Laboratory Instrumentation

Phase III = Testing and Evaluation
P = Test Production
S = Test Scoring
R = Test Records and Determination of Course Marks
A = Test Item Analysis
T = Correlation of Marks and Analysis of Trends
G = Career Guidance

Appendix D

Potential Uses of Computers in Science Education

(For the Pilot Stage of
Data Gathering from Science Teachers)

The Uses of Computers in Science Education

Activity I: The Preparation

- Curriculum Planning and Materials Preparation
  C.R.I.B., idea bank, custom illustration
- Professional Development
  pre-seminar contributions
- Institutional Coordination
  message facility, student records
- Library Searches
  `E.R.I.C.' searches
- Instructional Management Applications
  personalized, criterion-based, multi-functional

Activity II: Teaching/Learning

- Simulations
  explorations, lab-substitute, lab-supplement
- Laboratory Instrumentation
  data capture, device control
- Tutorial
  remedial discourse, heuristic branching
- Drill and Practice
  review, reinforcement
- Gaming
  competitive, motivating
- Electronic Chalkboard/Calculator
  notes, displays, alternate to film, OH projector
- Problem Solving
  model building, high-level language

Activity III: Testing and Evaluation

- Testing
  on-line, multi-functional
- Test Production
  retrieval/generation, manual/random
- Test Scoring
  marking
- Records
  mark maintenance, CMI prescriptions
- Analysis
  item or test revision
- Evaluation of Students/Program
  longitudinal tracking, revision
- Career Guidance
  CHOICES data bank

Appendix E

The Interview Questions

(For the Pilot Stage of
Data Gathering from Science Teachers)

Interview Questions - Pilot Stage

Warm-up

- What kind of computers do you have in your school?
- How long have you had these computers?
- Where are they situated in the school?
- Are they mobile or relatively fixed?
- What classes are using the computers?
- What out-of-class uses are other teachers making of the computers?

Current Uses

- What are you using the computers for?
- What programs are you using?
- How long have you/the department/the school had this/these computers?
- What effect has this useage had on your
    - teaching routines?
    - students?
- What did you need to learn in order to effect this useage?
- Where did you learn these skills/information?
- Is private study feasible for learning these skills?
- Do you need to be able to 'program' a computer to 'use' the computer?
- Is a background in electronics required?
- What personal obstacles did you overcome, e.g., Computer Mystique?

Projected Uses

- What would you like to do with the computers if you could?
- Do you have any programs in mind or know of anybody who is doing this?
- What time or money would be necessary for this use?
- What would you need to know before you could recommend this use to your department head or principal?
- What would you need to learn before you could effect this useage?

Proposed Uses

- How would the proposed use improve your teaching, if at all?
- Would you implement the use primarily for your benefit or for your students?
- Is the proposed use feasible in terms of current equipment or personnel?
- Would you need any training to implement the proposed use, as described?
- Would you participate in self-study or group training sessions to learn the requisite skills? Which?

Appendix F

School Jurisdictions Represented by Teachers Who Responded to the Questionnaire on Computer Uses

School Jurisdictions Represented by Teachers Who Responded to the Questionnaire

Calgary RCSS District #1
Calgary School District #19
County of Leduc #25
County of Ponoka #3
County of Strathcona #20
Edmonton Christian High School
Edmonton RCSS District #7
Edmonton School District #7
Grande Prairie School District #2357
High Prairie School Division #48
Red Deer RCSS District #17
St Albert PSS District #6
Strathcona-Tweedsmuir School

Appendix G

Correspondence to Science Teachers for the Administration of the Study

1984 02 06

Dear [name of teacher]

re: The Use of Computers in Science Teaching.

I am a chemistry teacher on Leave from the Edmonton Public School System and am attempting to determine 'what a teacher needs to know to use computers in science teaching.' The current phase of my program is a study of the way teachers are using computers in their science teaching.

In October 1982, during the Science Council's Flea Market, you 'signed-on' to a Log of 'Science Teachers Using Computers.' (You may recall that I later sent you a print-out of participants in that venture.) My studies have since then progressed to the more specific goals of attempting

1. to determine the current uses of computers made by selected science teachers and the nature of each teacher's experiences with these uses and
2. to determine other potential uses of computers envisioned ~~by these~~ selected science teachers.

Because of your expressed interest in using computers in science teaching, I am inviting you to participate in the current phase, a questionnaire wherein

a) typical uses of computers for teachers are described and
b) the responding teachers indicate their experiences with, and reactions to, these uses.

Normal protocol for contact, for purpose of research, between teachers studying at the University and practicing teachers requires that permission be granted by the teacher's employing school jurisdiction. If you wish to participate in this study, and I hope you will, please complete and return the coupon at the bottom of this page.

Of course, as part of the sharing of the benefits resulting from your involvement in the survey, a detailed summary of the results of the study will be sent to you and your employing school jurisdiction upon completion of the study.

I hope you can join in this project.

A. Allan PEET
5604 - 94 Ave
Edmonton, AB
T6B 0X6
(403)469-3320

Participating-Teacher Information:

Teacher's Name: ______________________________

Subjects Taught: ______________________________

School Name: ______________________(Elem/JrHi/SrHi)

School Address: ______________________________

School Telephone Nr.: __________________________

School District: ______________________________

1984 02 02

Dear

re: The Use of Computers in Science Teaching.

I am a chemistry teacher on Leave from the Edmonton Public School System and am attempting to determine 'what a teacher needs to know to use computers in science teaching.' The current phase of my program is a study of the way teachers are using computers in their science teaching. The study includes a questionnaire to selected teachers for the purpose of constructing a profile of

- the types of experiences with various uses of computers that are being made, or have been made, by those responding and
- the potential, for these teachers, of proposed uses of the computer for science teaching.

Because of your reported interest in this topic, I am sending you a copy of the questionnaire mentioned, which I would kindly ask you to fill out in some detail as part of my study. Embedded in the questionnaire is a summary of a recent review of the literature describing 'the uses of computers in science teaching'. Please use these descriptions of uses to guide your responses to the survey questions in the questionnaire.

Also, I would ask you to react to these uses of computers by drawing on your experiences with programs you have used or considered using and not to consider temporal constraints such as adequate software or hardware resources.

Of course, as part of the sharing of the benefits resulting from your involvement in the survey, a detailed summary of the results of the study will be sent to you and your employing school jurisdiction upon completion of the study.

I appreciate the thought and time that you give to this questionnaire and thank you for your assistance in my study.

A. Allan PEET
5604 - 94 Ave
Edmonton, AB
T6B 0X6
(403)469-3320

1984 05 22

Dear [Name of Teacher],

re: Interview - What does a teacher need to know
to use computers in Science Teaching?

This letter confirms our agreement by telephone, [Day], 1984 [month, date]:[time], to an interview concerning my study referred to above.

It is understood that this interview is scheduled for 1984 [month, date]:[time] at [Name of School].

I would prefer to audio-tape the interview if that is acceptable to you. You will be credited, along with the other teacher-participants, with having contributed to the study-at-large and statements made by you will, of course, be protected by anonymity.

I have attached a copy of the prompt sheet which I plan to use during the interview. This list of five major themes (found to recur in the responses to the questionnaire) will form the framework for the information gained from the interview about your experiences with a limited number of computer uses. I have also included under each theme supplementary questions that suggest specific issues that you may wish to address in your comments.

Thank you for agreeing to assist in this final stage of data collection for my study. I am looking forward to meeting you.

A. Allan PEET
(403)469-3320

Appendix H

Schedule of Categories of Knowledge and Questions for Interviews in the Main Stage of Data Collection from Science Teachers

Learning to Use Computers in Teaching - Themes, Questions

"To enable your activity in {Phase} {use}, for which you indicated you have experience as a {User/Designer/Programmer /Consultant}, what did you need to know or learn about:

A) fundamental operating and programming knowledge? Eg.,
  - What minimum knowledge about the operation of a computer would be needed to effect this computer use?
  - What programming knowledge is necessary?
  - In what manner does the level or nature of operating/ programming knowledge differ for teachers and students?

B) hardware and peripherals that were needed? Eg.,
  - What brand and type of equipment have you employed in this use of computers?
  - What knowledge would you consider worthwhile when purchasing equipment for this use?
  - As a user of this equipment, what maintenance skills do you consider sufficient?

C) software or courseware to be used? Eg.,
  - What are your sources of information about types or specific programs that are available?
  - What kinds of sources do you have for the actual programs you have used?
  - What factors do you take into account when considering the development of a program for this use?
  - What criteria do you employ when evaluating a program for possible use?

D) implementation or application in the classroom/school?
  - What were the sources that suggested to you this use of the computer?
  - What actions did you take to begin using the computer?
  - What difficulties did you experience and how did you resolve them?
  - What support system do you use when you need assistance with this use of the computer?
  - What specific assistance have you received from other persons or agencies?
  - What are the limitations to `good' science teaching associated with this use of computers?

E) impact on you as a teacher? Eg.,
  - What is your role as a teacher associated with this use of the computer?

F) any other dimension of the computer/science teaching interface?
  - What are the factors (other than those referred to already) that determine the likelihood of you using the computer for this use?

Appendix I

Grid of Level and Nature of Interest in Using Computers in Science Teaching Reported by Respondents to the Questionnaire

Nature of Usage/Feasibility by Questionnaire Respondents

	Phase I						Phase II								Phase III					
T#	CM	PD	CT	LA	IM	O	PS	Sm	Tt	Gm	DP	EC	LI	O	TP	TS	TR	IA	MT	CG
01	3.	.	.	.	.	.	.	2A	3.	.	.	.	.	.	5A	.	7A	.	.	.
02	6A	.	.	.	.	2A	4o	5A	4o	2a	.	.	.	.	5A	.	6A	.	3a	2a
03	4.	2A	.	.	3a	.	.	3A	4A	2a	4A	3a	.	.	7a	.	7A	.	.	.
04	.	.	.	.	3a	.	.	4a	4a	2a	.	.	.	.	6A	4a	7A	4A	.	.
05	4a	.	.	.	.	.	.	.	.	5A	5o	.	.	.	1A	6A	6A	6A	.	.
06	.	.	.	.	.	.	.	.	.	.	3o	.	.	.	1A	.	4A	.	.	.
07	.	.	.	.	.	.	>	.	>	.	3o	.	.	.	4A	.	6A	.	.	.
08	6A	.	.	.	.	.	.	4a	5a	2.	4A	3a	.	4A	6A	.	6A	.	.	.
09	5A	.	.	.	6A	<	.	4a	.	.	4.	.	2o	.	6A	.	6A	.	.	4a
10	3.	.	.	4A	.	.	4A	.	.	2a	3.	1o	.	.	.	.	2A	.	2a	.
11	.	.	.	.	.	5>	.	.	.	.	1o	.	.	.	.	.	5A	.	.	.
12	.	.	.	.	.	3.	.	.	.	3.	3.	.	.	.	.	.	4.	.	.	.
13	5A	.	3.	.	.	.	6A	4A	4.	c	3o	1o	1o	.	.	.	6a	.	3.	.
14	>	.	.	.	.	7o	.	5A	.	.	.	5A	.	.	2a	.	2.	.	.	.
15	2A	3o	3o	.	4>	.	.	5a	>	4o	4o	4o	.	.	5A	4.	4A	4A	4a	5a
16	.	.	.	3.	3.	.	.	3.	3a	.	1a	3a	.	.	3A	3A	3A	.	.	.
17	7A	3a	.	5A	4>	4>	5a	4A	2a	.	2o	5o	4a	.	7A	.	4A	.	.	.
18	6A	.	2.	3.	3a	.	3.	4a	3A	3a	2a	4o	.	.	.	.	7A	3.	.	2a
19	1.	.	.	.	5o	.	.	.	.	.	.	.	.	.	5A	.	.	.	.	.
20	.	.	.	.	.	>	.	.	.	.	.	.	.	.	.	.	4A	.	.	.
21	2A	.	.	.	.	.	.	.	3o	3o	.	.	.	.	4A	.	2A	3a	.	.
22	6A	.	.	.	3a	3o	.	5A	3.	.	.	3a	5<	.	6A	3a	7A	4o	.	.
23	5A	.	.	.	.	>	.	3.	.	.	.	.	.	.	.	.	6A	.	.	.
24	.	.	.	.	>	.	.	.	.	.	.	.	.	.	4A	.	3a	3A	1a	1o
25	.	.	.	.	1.	.	.	.	.	.	.	.	.	.	.	.	3a	.	.	1a
26	2.	.	.	.	.	.	3a	2a	.	3o	2.	3.	.	.	4A	1.	4a	.	.	1a
27	3A	.	>	.	4.	.	4a	5A	4.	.	4a	.	3<	.	.	.	5A	.	.	2a
28	3A	.	.	.	2c	6A	.	4a	4A	3o	4o	2.	.	.	5A	5A	6A	.	.	.
29	6A	.	.	.	.	.	.	.	.	.	4A	.	.	5o	6a	2a	6A	.	.	.
30	2.	.	4o	.	4a	.	5a	.	.	4o	4.	3o	5o	.	4a	5a	6a	3o	.	.
31	5A	1o	.	4A	>	.	.	2o	2.	3a	3A	.	1.	.	5A	.	6A	.	.	1a
32	.	.	.	.	.	.	.	.	.	3.	3.	.	.	.	.	.	.	.	.	.
33	4.	.	.	.	.	.	.	4A	4.	.	.	4.	.	.	.	.	5a	.	.	.
34	7A	6A	3o	.	>	7A	5A	6A	2A	.	.	.	.	.	7A	.	6A	.	.	.
35	4a	4a	.	.	>	.	.	2a	3o	2a	4A	4A	.	.	3A	3o	5A	.	.	2a
36	4a	4a	>	.	.	.	4A	7A	.	3A	2A	.	4o	.	6a	1.	1.	.	.	.
37	3A	.	.	2o	4A	.	3A	4o	5A	.	3A	2o	2o	.	4A	4A	2o	4A	.	.
38	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	3A	.	.	.
39	6A	3.	4A	.	5A	4.	7A	7A	5A	6.	7A	4A	.	5.	5A	2.	2a	5A	.	5A
40	6A	3.	6a	.	.	.	.	4A	3.	.	6A	.	.	5o	2a	3o	7a	4o	4o	2a
41	4.	.	.	.	5A	.	4.	.	4a	.	6A	.	.	.	4a	.	6A	.	.	.
42	3A	.	3a	2.	>	.	>	.	3A	.	3A	.	.	.	5A	.	5A	.	.	.
43	2.	.	.	.	3.	.	3.	.	5A	.	3a	.	.	.	5a	2a	.	2.	.	.
44	4A	.	.	.	>	.	3.	4a	4A	1a	4a	.	.	.	3.	4A	.	3A	.	.
45	3A	.	.	.	>	.	.	.	.	.	.	.	.	.	6A	.	.	.	.	.
46	6A	.	.	4A	4A	.	.	5A	1A	.	.	.	.	.	6.	.	7.	7A	.	.
47	.	2A	.	.	3a	.	.	5A	.	.	7A	3o	3.	.	4A	4.	6A	.	2A	2A
48	6A	.	.	.	>	.	.	.	.	.	.	.	.	.	3A	.	3A	3a	3a	3a
49	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	2o
50	3.	.	.	.	1A	.	1A	.	.	.	2o	.	.	.	1.	.	1.	.	.	.

Notes: 1. The response sum of the levels of experience and feasibility are indicated in each cell (except zero which is coded as '.').
2. The maximum possible for each use is 7. (4 for experience + 3 for feasibility = 7)

Users:

T# = Sequentially Assigned Number of each Teacher-Returned Questionnaire

Uses:

Phase I = Preparation for Teaching
CM = Curriculum Planning and Materials Preparation
PD = Professional Development
CT = Communication between Schools and/or Teachers
LA = Library Applications
IM = Instructional Management

Phase II = Teaching
PS = Problem Solving
Sm = Simulations
Tt = Tutorial
Gm = Gaming
DP = Drill and Practice
EC = Electronic Chalkboard
LI = Laboratory Instrumentation

Phase III = Testing and Evaluation
TP = Test Production
TS = Test Scoring
TR = Test Records and Determination of Course Marks
IA = Test Item Analysis
MT = Correlation of Marks and Analysis of Trends
CG = Career Guidance

Usage:

A = specific educational application,
a = general educational application,
o = use other than in education,
<,> = see other listed use in direction noted.